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ABSTRACT

The two student notebooks in this set provide the basic outline and assignments for the third year of a four year senior high school unified science program. This course is the more technical of the two third-year courses offered in the program. The first unit, Extensions of the Particle Theories, deals with slide rule review, molecular theory and the gas laws, mole concept, chemical periodicity, chemical reactions and related concepts and problems. The second unit, Energy - Time Relationships in Macrosystems, presents an analysis of vector quantities, interactions in static equilibrium systems, and interactions in dynamic systems. The third and final unit, Energy - Time Relationships in Particulate Systems, is concerned mainly with chemical energy distribution, reaction rates, and chemical equilibrium. The materials for each of the sub-units include: a list of required and recommended readings from various other books; questions for consideration in introducing a lesson; a brief background reading; a basic outline of the lectures with space provided within the outline for notes; laboratory activities and investigations; laboratory problem reports and other kinds of assignments (discussion questions, fill-ins, problems); and summary statements and review questions. Numerous diagrams and illustrations are included. (PR)

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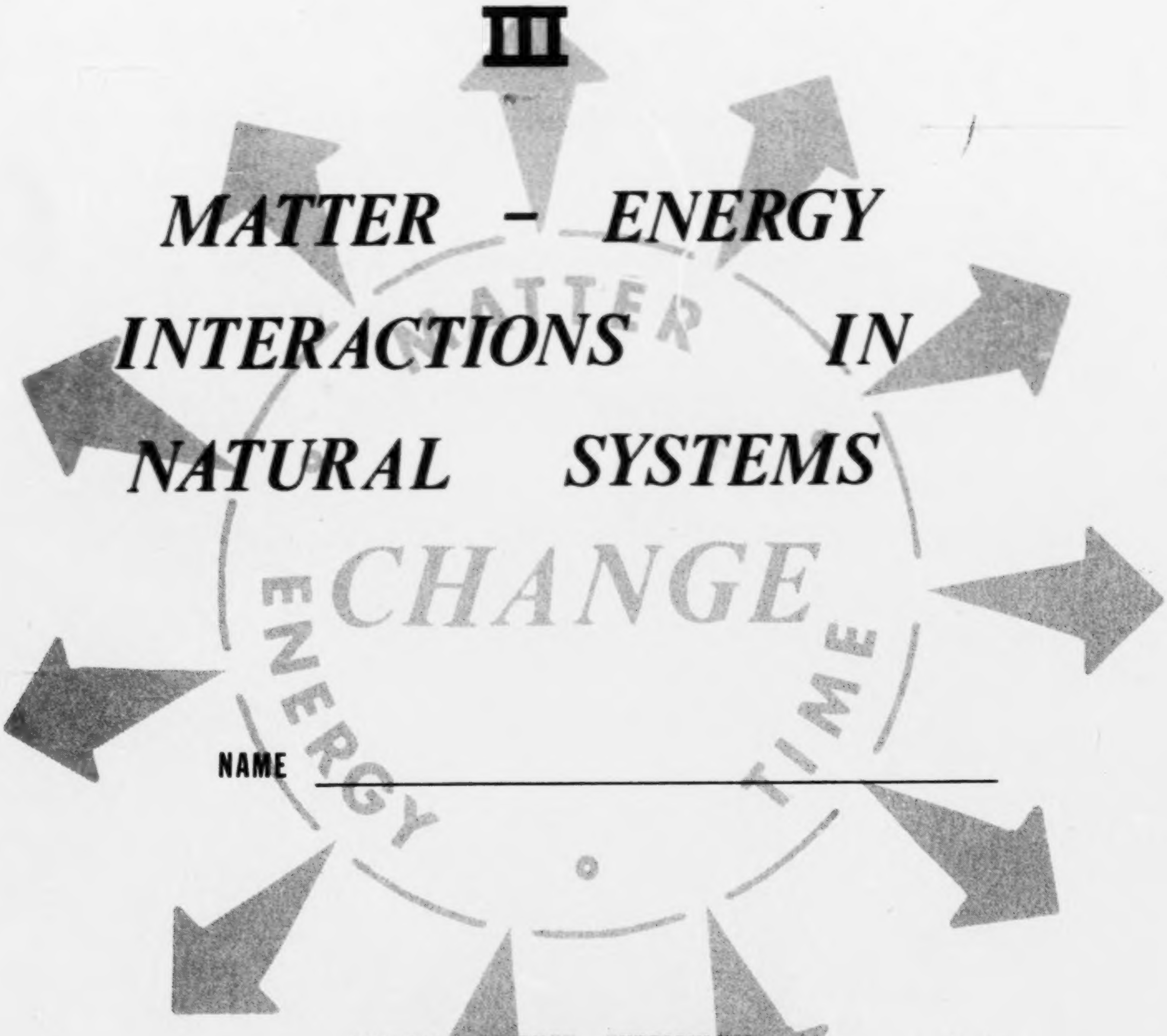
SCIENCE

III

MATTER - ENERGY INTERACTIONS IN NATURAL SYSTEMS



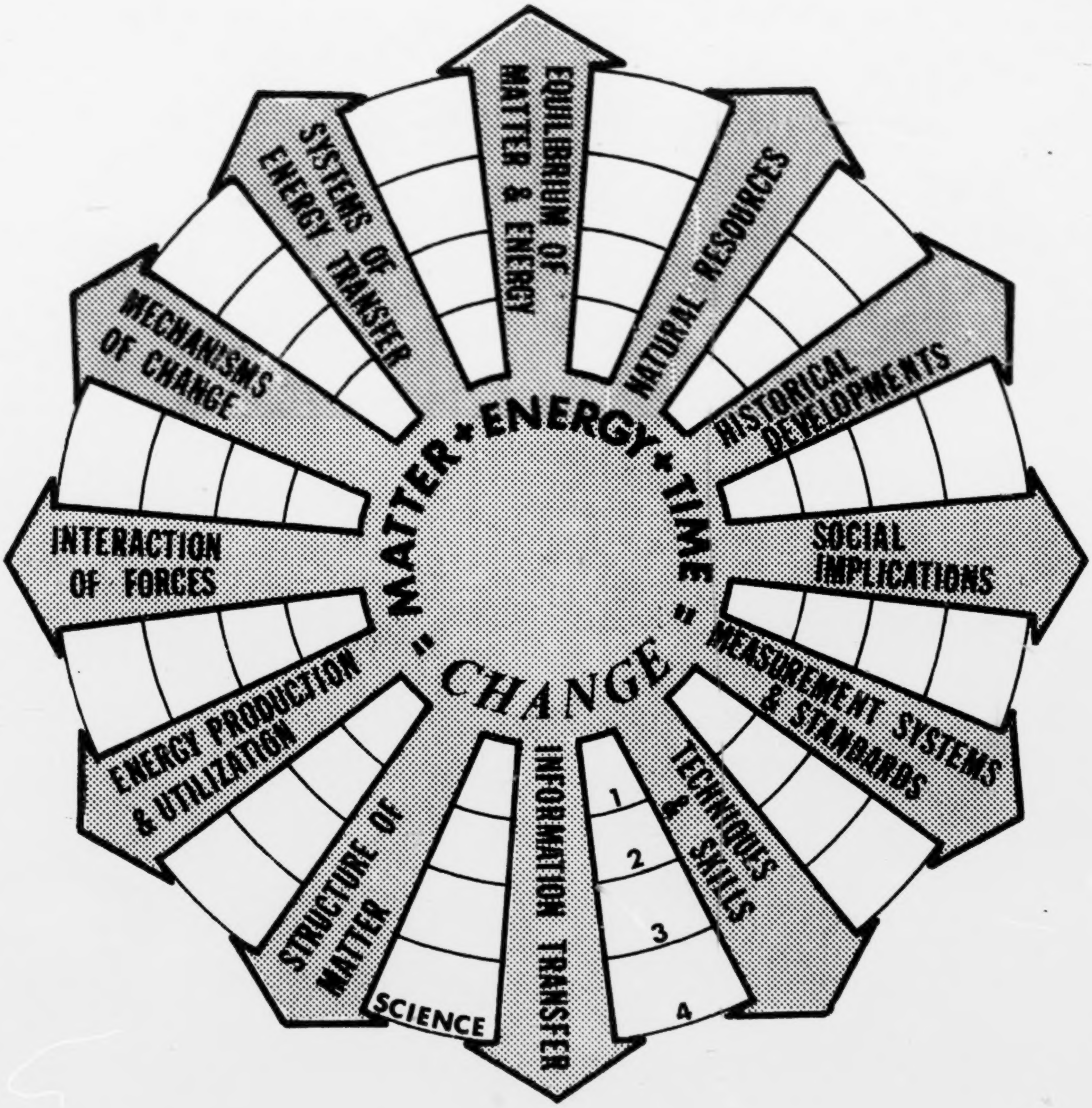
NAME ______________________________

UNIFIED SCIENCE CURRICULUM
MONONA GROVE HIGH SCHOOL
MONONA, WISCONSIN 53716

SE 012 149
Part 1

UNIFYING THEMES

MONONA GROVE UNIFIED SCIENCE PROGRAM



EQUILIBRIUM OF MATTER & ENERGY
NATURAL RESOURCES
HISTORICAL DEVELOPMENTS
SOCIAL IMPLICATIONS
MEASUREMENT SYSTEMS & STANDARDS
TECHNIQUES & SKILLS
1
2
3
4
INFORMATION TRANSFER
SCIENCE
STRUCTURE OF MATTER
ENERGY PRODUCTION & UTILIZATION
INTERACTION OF FORCES
MECHANISMS OF CHANGE
SYSTEMS OF ENERGY TRANSFER
" MATTER + ENERGY + TIME "
CHANGE

INTRODUCTION

I. Class Procedures and Regulations

A. Grouping

1.	Large Groups (50-55 Students)	Rooms -- 67, 61
2.	Laboratory Groups (24 Students)	Rooms -- 61, 73, and 69
3.	Small Groups (15-18 Students)	Rooms -- 61, 73, 69, 67, 65 and other available rooms

When groups move from one room to another during a class session, the movement is expected to be accomplished quickly and quietly.

B. Personal Responsibility in the Classroom

1. When the bell signaling the beginning of a class session sounds, students are expected to come to order without further direction. Students not in their assigned seats at this time are considered to be tardy.
2. Students reporting to class late must present an "admit to class" pass.
3. The class will be dismissed by the teacher, not the bell, at the end of the class session.
4. Students detained by the teacher after the bell should obtain an admit to class pass before leaving the room.
5. Before leaving the classroom!
    a. Check your desk including the shelf and floor area to be sure that they are cleared of debris and in order.
    b. Place your chair under the desk.
6. The science department office located between rooms 61 and 65, is not to be used as a passage way by students.

C. Note Taking

1. The student notebook provides a basic outline of the course content.
2. Regular, careful, note taking in large group sessions is required in order to make the student notebook a useful reference for study.
3. An audio tape on effective note taking is available in the Resource Center.
4. Notebooks will be collected periodically to evaluate the quality of note taking.

D. Assignments

1. Assignment schedules will be given periodically. These schedules should be used to help budget time for homework and study for quiz sessions and hour examinations.

2. Types of homework assignments

   a. Reference reading:

      (1) Reading assignments will be made from selected references located in the Resource Center.

      (2) Generally the required reading assignments will also be available on audio tape.

      (3) "Check tests", one or two questions, will frequently follow a reading assignment.

   b. Problems, exercises and discussion questions:

      Duplicate copies of all problem assignments, exercises and discussion questions appear in the notebook. Carbon copies are handed in for evaluation.

   c. Laboratory reports - to be completed on special laboratory report forms.

3. Regulations pertaining to homework assignments

   a. On days when assignment is due at the beginning of the class session homework will be collected when the bell rings.

      (1) Problems, exercises or discussion questions missing after the collection of homework will be recorded as an F and be reflected in the Individual Performance Grade.

      (2) When excused absence is a factor the F may be converted to full credit provided that the assignment is completed within a specified period.

      (3) Laboratory reports missing at the time of collection will be graded F in Knowledge and Skills and affect the Individual Performance Grade.

      (4) If excused absence is not a factor, late laboratory reports may be submitted for a maximum of ½ credit in Knowledge and Skills.

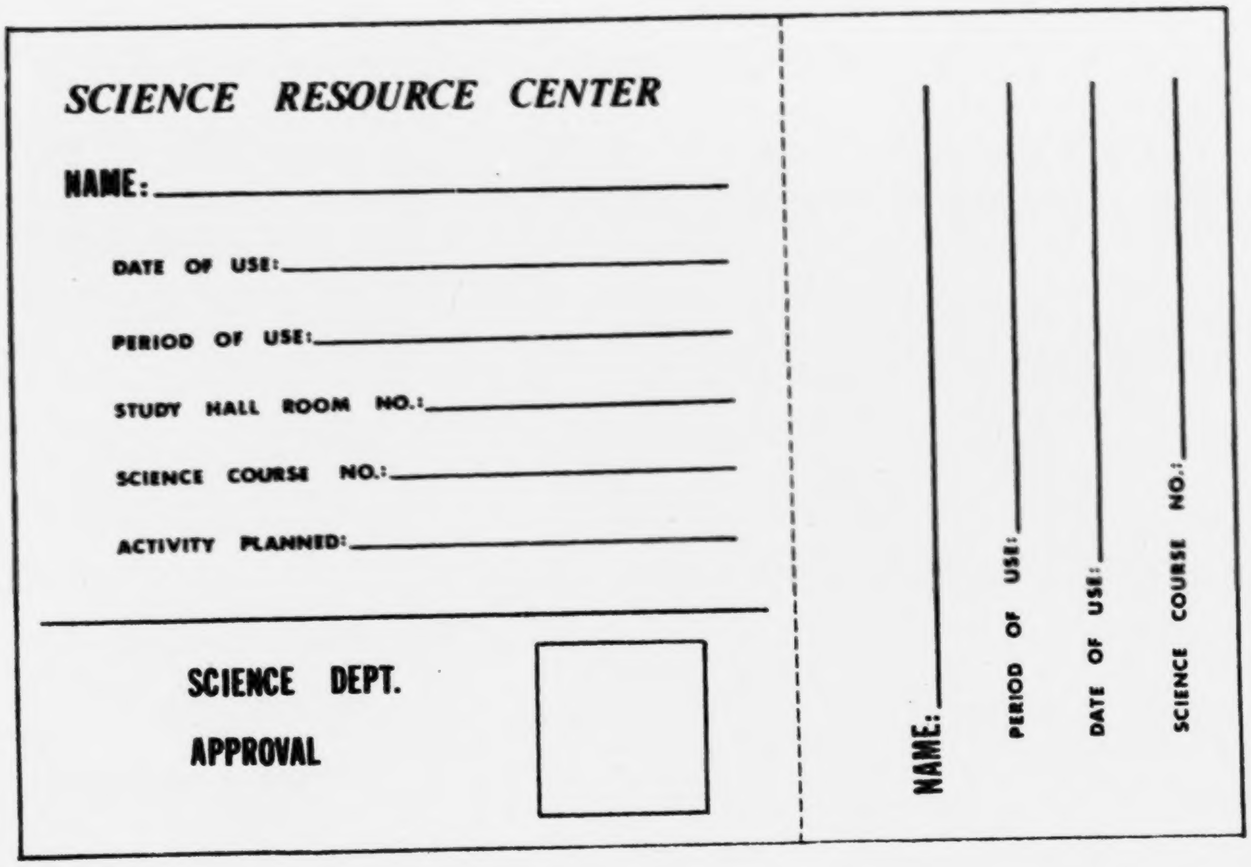
   b. Students absent from class are responsible for arrangements to complete assignments missed.

      (1) Assignments not handed in the day after returning to class will be graded as F, except in cases where requests for an extension of time have been approved.

      (2) Arrangements for making up a scheduled quiz or an hour examination must be completed the day the student returns to class. Any quiz or hour exam not made up will be averaged as F in the Knowledge and Skills Grade.

II. Science Resource Center

A. Use of the Resource Center Facilities



SCIENCE RESOURCE CENTER

NAME:

DATE OF USE:

PERIOD OF USE:

STUDY HALL ROOM NO.:

SCIENCE COURSE NO.:

ACTIVITY PLANNED:

SCIENCE DEPT. APPROVAL

NAME:

PERIOD OF USE:

DATE OF USE:

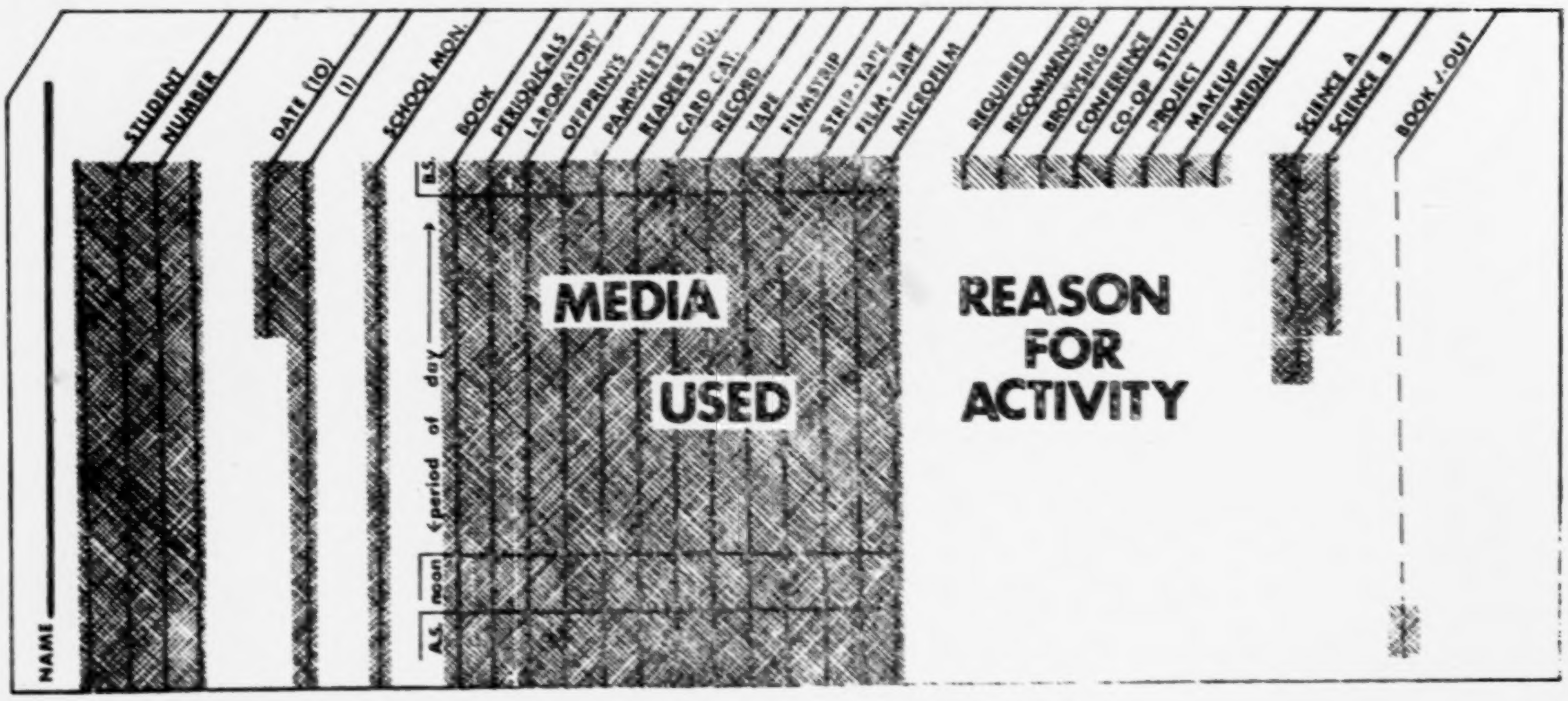
SCIENCE COURSE NO.:

1. The Resource Center may be used during any regularly scheduled study hall period by the "pass" system.
2. The Resource Center will be open from 12:15 to 12:45 every Tuesday, Wednesday, and Thursday noon.
3. Students wishing to use the Resource Center Facilities before or after school may do so by appointment.
4. Students must demonstrate the degree of self discipline necessary for effective independent or cooperative study in the Resource Center.

B. Circulation of Resource Center Reference Materials

1. No materials will be checked out during the school day.
2. Books, magazines, offprints, and special materials may be checked out on an "overnight" basis only. Check out period is from 3:45 to 4:00 p.m. daily.
3. All materials must be returned by 8:00 a.m. the next day.
4. Failure to comply with any of the above procedures will be reflected in the Citizenship Grade.

C. Use of the Porta-Punch Card


NAME
STUDENT
NUMBER
DATE (10)
(1)
SCHOOL MON.
BOOK
PERIODICALS
LABORATORY
OFFPRINTS
PAMPHLETS
READERS GU.
CARD CAT.
RECORD
TAPE
FILMSTRIP
STRIP-TAPE
FILM-TAPE
MICROFILM
REQUIRED
RECOMMENDED
BROWSING
CONFERENCE
CO-OP STUDY
PROJECT
MAKEUP
REMEDIAL
SCIENCE A
SCIENCE B
BOOK / OUT
B.S.
period of day
noon
A.S.
MEDIA
USED
REASON
FOR
ACTIVITY

1. Print your name on the card.
2. Punch out the correct information on the shaded (red) area.

D. Guide to Student Use of the Science Resource Center

1. The Science Resource Center is designed and equipped to provide an opportunity for students to do independent or cooperative study in the area of science.
2. Students who come to the Resource Center must have a specific purpose which requires the use of the facilities in the Center!
3. Students who use the Resource Center Facilities must record the nature of their activity in the Center by use of the Porta-Punch Card.
4. All cooperative study between two students must be done at the conference tables. Students sitting at the study carrels are expected to work individually without any conversation with other students.
5. All students are encouraged to take advantage of the opportunities that the Resource Center provides for individual help with any problems or difficulties experienced in their science course.
6. The use of the Resource Center Facilities requires self discipline on the part of the student in order to develop effective individual study skills. Students who are unable to exercise the self discipline required to maintain an atmosphere conducive to independent study will not be permitted to use the Resource Center Facilities until such time that they can demonstrate this ability.
7. Maintenance Responsibilities
   a. Turn volume off when headsets are not in use.
   b. Leave all reference books on the carrel shelf in good order. All cataloged books and periodicals are to be returned to the proper space in the drawers or shelves.
   c. Keep desk storage area free of debris and desk surfaces clean.

III. Grades and grading

A. Basis for the evaluation of Individual Performance and School Citizenship:

*See accompanying sheets or student handbook for points considered in grading these categories. Individual Performance and School Citizenship will be evaluated three times each quarter.

B. Basis for the evaluation of student progress in the area of Knowledge and Skills:

1. The grade point system

4.0 3.9 3.8	4.3 A+
3.7 3.6 3.5	4.0 A
3.4 3.3 3.2	3.7 A-
3.1 3.0	3.3 B+
2.9 2.8 2.7	3.0 B
2.6 2.5	2.7 B-
2.4 2.3 2.2	2.3 C+
2.1 2.0 1.9	2.0 C
1.8 1.7 1.6	1.7 C-
1.5 1.4	1.3 D+
1.3 1.2 1.1	1.0 D
1.0 .9	.7 D-
.8 .7 .6 .5	.3 F+
.4 .3 .1 .0	.0 F

2. Determination of grade point

Daily Work - ½ of Knowledge and Skills Grade

Quizzes a. short 5 minute unannounced test covering material presented in large group sessions or homework assignments

b. 15-30 minute announced test

Written laboratory problem and investigation reports

Hour Examinations - ½ of Knowledge and Skills Grade

Daily work and hour examinations not completed will be averaged as zero.

C. Final Total Growth Grade

1. Each of the four, quarterly, total growth grades plus the Final Evaluation are averaged equally to give the final Total Growth Grade in the course.

2. Final Evaluation

a. The final written examination in the course will count as one-half of the Final Evaluation.

b. A final appraisal of Individual Performance and School Citizenship will determine the remaining half of the Final Evaluation Grade.

FACTORS DEFINING INDIVIDUAL PERFORMANCE

Works up to ability

1. Does work which compares favorably with ability as measured by test scores.
2. Does daily work which compares favorably with best work done in a grading period.
3. Tries to make the best use of his particular talents and opportunities.
4. Carefully completes each day's assignment.
5. Reworks and corrects errors in assignments after class checking.
6. Goes beyond regular assignments to learn more about the subject.
7. Spends time reviewing.
8. Shows improvement rather than staying at one point.

Has a positive attitude

1. Has a sincere desire and interest in learning.
2. Is willing to try - is willing to be exposed to new information and ideas.
3. Has respect for the opinions of others.
4. Accepts correction well and constantly tries to improve.
5. Takes pride in his work.
6. Responds as well to group instruction as to individual instruction.
7. Does not argue over trivial points.
8. Does not show negative feelings in class - straightens things out alone with teacher.
9. Is willing to accept special jobs.

Shows self-direction

1. Demonstrates ability to carry on independent or cooperative study using Resource Center materials.
2. Works for understanding rather than a grade.
3. Is self-starting and self-sustaining.
4. Does his own work - has confidence in it.
5. Tries assignments himself before seeking help.
6. Knows when and how to seek help.
7. Initiates makeup assignments and does them promptly.
8. Is resourceful- uses imagination.
9. Settles down to work immediately.
10. Shows initiative.

Plans work wisely

1. Completes assignments and turns them in on time.
2. Is prepared for class - brings all necessary materials.
3. Makes good use of study time.
4. Follows directions.
5. Anticipates needs in work projects.
6. Organizes time so there is no last minute rush job.
7. Moves quickly and quietly when given an assignment.

FACTORS DEFINING SCHOOL CITIZENSHIP

Is courteous and considerate of others

1. Is courteous to other students, to teachers or any person with whom he comes in contact, for example the custodial staff.
2. Is quiet and attentive in class discussion.
3. Listens carefully to student questions, answers and comments as well as to those of the teacher.
4. Uses only constructive criticism - avoids ridicule.
5. Is tolerant of errors made by others.
6. Receives recognition before speaking.
7. Is ready to begin work when the bell rings.
8. Accepts the "spirit" as well as the letter of school regulations.
9. Shows halllway conduct which is orderly and in good taste.
10. Shows good assembly conduct.
11. Is quiet and attentive during P.A. announcements.
12. Is quiet in hallways when school is in session.
13. Carries out classroom activity in a quiet and businesslike manner.

Is responsible

1. Demonstrates self discipline necessary for effective use of Resource Center Facilities.
2. Keeps appointments.
3. Carries out assigned tasks.
4. Can be left unsupervised for a period of time.
5. Gets to class on time.
6. Meets obligations, fees, etc.
7. Returns borrowed items.
8. Has a good attendance record.
9. Keeps name off library list.
10. Presents excuse for absence.
11. Returns report card on time.

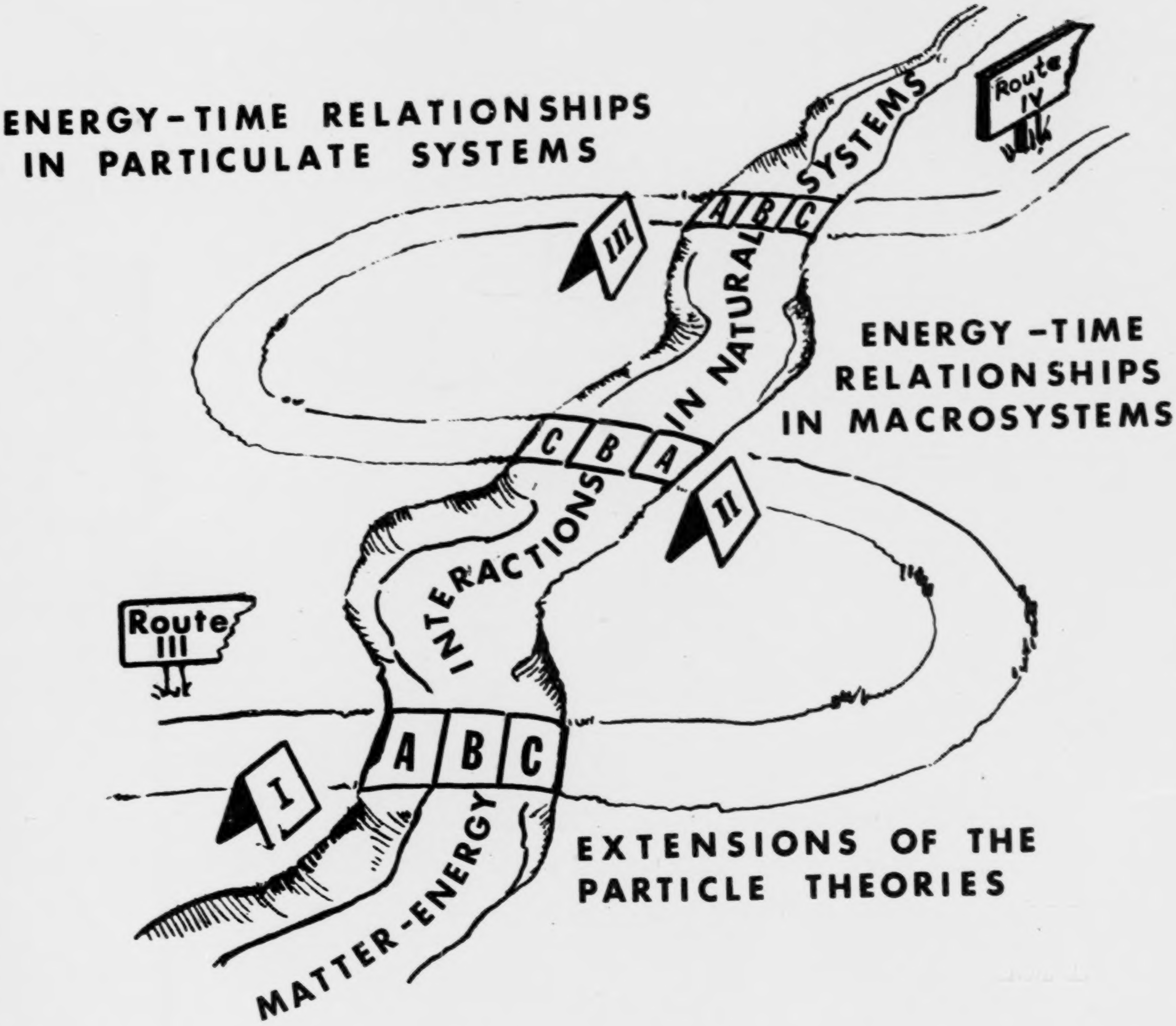
Contributes his share

1. Works to develop and uphold the good reputation of the school.
2. Participates in class discussion in a constructive manner - asks questions as well as volunteering information - shares ideas.
3. Participates in at least one school activity as a cooperative, contributing member.
4. Accepts jobs such as taking part in panels, putting up bulletin boards, helping direct class activities, getting information.
5. Brings examples, clippings, supplementary materials to class.
6. Contributes to success of class in a physical way - straightens chairs, pulls blinds, etc.

Is a good leader or follower

1. Cooperates willingly with the majority even though his point of view is with the minority.
2. Works constructively to change practices he is not in agreement with.
3. Works willingly with any group, not just his particular friends.
4. Helps class move along positively.
5. Leads in class discussion.
6. Responds to suggestions.

SCIENCE IIIA


ENERGY-TIME RELATIONSHIPS IN PARTICULATE SYSTEMS
Route IV
A B C
III
ENERGY-TIME RELATIONSHIPS IN MACROSYSTEMS
C B A
II
Route III
A B C
I
EXTENSIONS OF THE PARTICLE THEORIES
MATTER-ENERGY INTERACTIONS IN NATURAL SYSTEMS

SCIENCE IIIA

MATTER-ENERGY INTERACTIONS IN NATURAL SYSTEMS

EXTENSIONS OF THE PARTICLE THEORIES

Interactions in Gases

Mole Concept

Mechanism of Chemical Reactions

ENERGY - TIME RELATIONSHIPS IN MACROSYSTEMS

Analysis of Vector Quantities

Interactions in Static Equilibrium Systems

Interactions in Dynamic Systems

ENERGY -TIME RELATIONSHIPS IN PARTICULATE SYSTEMS

Energy Distribution

Reaction Rates

Equilibrium in Particulate Systems

MATTER - ENERGY INTERACTIONS IN NATURAL SYSTEMS

"One of our innate characteristics, as human animals, appears to be a need to "understand" what goes on around us. Because of the way our minds are constructed, we cannot avoid seeking "causes" for the "effects" that we observe through our sensory mechanisms. Since physiological limitations prevent our holding in mind and dealing simultaneously with more than a few related concepts, we continually strive to reduce to a minimum the number of fundamental causes or principles that we employ to explain what we observe. There is more than a little of the scientist built into the genetic specifications of each human individual.

The fact that the universe in which we live is largely susceptible to understanding in terms of the kind of cause/effect principles that man naturally searches for no longer seems to be the mysterious coincidence that it once appeared. We now appreciate how the operation of evolution and natural selection must automatically, in time, bring to dominance animal species with behavior and thought patterns that adapt them well to their environment. If the universe operates largely on the basis of cause/effect relationships, we would expect that the dominant species would owe its dominance largely to its evolutionarily developed ability to deal competently with cause/effect situations.

A paradoxical consequence of man's natural predilection for logical thought was his invention of the important concept of the supernatural. He had a compulsion to explain what he observed, but his ability to trace cause/effect relationships was limited to the simpler, more immediate phenomena of his environment. To provide an "explanation" for matters he despaired of understanding, he invented the concept that these matters lay outside the domain of natural cause/effect principles -- that, in short, they were "supernatural". This was appealing to the orderly human mind; it provided a neat means of differentiating between the aspects of life that ought to be dealt with rationally and those which should be just accepted but not analyzed.

The development of science can be described as the process of transferring one after another aspect of human experience from the supernatural category into the realm of natural law. The rain and wind, lightning and earthquake, the rising and setting of the sun and stars have long since been accepted as the manifestations of the workings of the laws of gravity, mechanics, thermodynamics, and electricity. In more modern times the aurora borealis, the Van Allen belt, the propagation of radio waves, the properties of chemical dyes and plastics, and the principles of rocket propulsion are all "understood" in terms of generally accepted natural laws. And there are surprisingly few of these laws. With a couple of dozen subnuclear particles and a similar number of fundamental physical laws we are today able to derive explanations for a tremendous variety of physical and chemical phenomena, and most of those we cannot explain appear to be beyond our reach because of their complexity, rather than because of any inadequacy in the fundamental laws. To be sure, the last word has not yet been said relative to the basic particles from which matter and energy are derived and we have good reason to believe that we have not yet precisely formulated the natural laws, since new discoveries require us to refine and restate them from time to time. We cannot even be sure that there do not still exist undiscovered phenomena whose explanation will require

2 major additions to our present statement of the body of natural law. However, all this is beside the point. The fact that our knowledge of the laws and particles that govern and inhabit the universe is less than perfect must not obscure the tremendous body of evidence attesting to the orderliness of all natural phenomena that are generally classified as "physical" or "chemical." In this very broad area the crutch of a supernatural explanation now has to be used almost not at all.

Almost, but not quite. The explanations of physical phenomena must always start with the fundamental particles and the natural laws. Assuming the laws always existed and the particles were somehow provided in suitable number and distribution, plausible theories can be devised for the formation of the stars, the plants, the galaxies, and even for the subsequent course of billions of years of geologic development that have made of the earth what it is today. But since science is by its very nature based upon the process of reasoning from cause to effect, or of deducing probable causes from known effects, it is intrinsically incapable of carrying us back behind first causes. No scientist can "explain" the natural laws on which his science is ultimately based. He may invent a term such as "gravitational attraction" to enable him to discuss a phenomenon he wishes to deal with, and he may agree with other scientists on techniques for measuring the gravitational attraction between material objects. He may then perform experiments that ultimately permit him to deduce relations, or "laws," connecting gravitational forces and the masses and positions of the bodies involved. Thus he can learn how to predict the gravitational effects that will be produced by a specified configuration of objects or, conversely, to arrive at valid configurational deductions in terms of measured gravitational forces. But what *is* gravity, really? What causes it? Where does it come from? How did it get started? The scientist has no answers. His delineation of the relations between gravitational forces and other properties of matter and space, and his discovery that the relationships so delineated are immutable and unchanging, may cause him to develop such a sense of familiarity with gravity that he is no longer curious about it. Nevertheless, in a fundamental sense, it is still as mysterious and inexplicable as it ever was, and it seems destined to remain so. Science can never tell us why the natural laws of physics exist or where the matter that started the universe came from. It is good that our ancestors invented the concept of the supernatural, for we need it if we are to answer such questions.

While the physical scientist has not been able to dispense completely with the concept of the unexplainable or supernatural, he has at least managed to consign it to a corner of his mind where it does not greatly interfere with his day-to-day activities. He accepts as "given" the laws and particles of nature and spends little time worrying about the metaphysical problems associated with their origin. However, *he accepts absolutely nothing else as given*. He conceives of the world of physical and chemical phenomena with which he deals as a completely orderly and lawful world, with every detailed event, whether it be the formation of a new galaxy or the fall of a raindrop, being the effect of causes which are themselves the effects of other causes, and so on, going back ultimately to the fundamental particles and the basic laws of the universe. Even the existence among his laws of a principle of indeterminacy limiting the precision with which the future can be predicted does not permit the entry of caprice into the world of the physical scientist. Within a calculable and frequently very narrow range of uncertainty, the future is completely determined by the past. Given the laws and the particles, all else follows inexorably.

It is a measure of how far the modern world has come that few who read the preceding paragraphs will find either strange or objectionable the ideas expressed there--as long as they are clearly understood to relate only to the properties of inanimate matter. But when it comes to biological science, a different situation exists. There is by no means universal agreement on the extent to which living organisms resemble nonliving matter in having structure and properties determined entirely by the operation of immutable and unchanging natural law. Many are convinced that there is a basic difference between biological and physical phenomena in the degree of their ultimate scientific explainability. And even those who believe generally in the validity of natural law in biology may still feel that the laws applicable to living matter differ in profound essentials from those which control nonliving matter.

In former periods it was not difficult, even for practicing scientists, to employ entirely different philosophies when interpreting biological and physical phenomena. There were obviously vast differences between living creatures and inanimate objects. The overall properties of reproduction, growth, purposive behavior, adaptability, and the like just did not exist in the world of the physical scientist. And even when the structural and functional details of living organisms were investigated, the conspicuous features were found to be complex organs, nervous systems, tissues, and cells that seemed to have no nonbiological counterparts. Since the biologist possessed the normal human genetic endowment, he could not help looking for cause/effect relationships, or "natural laws," to help explain the complexities with which he had to deal in terms of a smaller number of simpler concepts. In this he was partially successful, but his laws, dealing with such things as the response of living organisms or parts of living organisms to environmental change, had little resemblance to the comparatively simple and mathematical relationships the physicist was steadily establishing among his particles and forces. Biology and physics appeared to be entirely separate fields.

The biologist, with subject matter incomparably more complex than that of the physicist, had an even greater need for recourse to the supernatural to bolster the underpinnings of his science. For this purpose the particles and laws of the physical scientist dod not seem to be relevant. Instead, there appeared to exist underlying purposive and directive forces in living organisms of a quality lying completely beyond the reach of cause/effect considerations. The terms "vital force" and "vitalism" were coined to represent the many aspects of the phenomena of life that, it was believed, would never be susceptible to scientific explanation.

There was a certain tidiness about the clear cleavage between biology and physics, each possessing its own religious dogma. Such separation also had the great advantage of consistency with one of the most humanly compelling of all philosophic tenets--the anthropocentric notion placing man above and beyond the workings of natural law designed for the regulation of an impersonal world. For the idea of the fundamental irreconcilability of life processes with the principles of physical science has always been a popular one almost automatically accepted as true, at least until proved false by overwhelming evidence.

Nevertheless, with the growth of knowledge both in the physical and the life sciences, the neat separation between the fields became difficult to maintain. Despite the essential convictions of practicing scientists, biology and physics had a tendency to come together. In retrospect, it seems more than coincidental that the event generally considered to have launched biology as a ture science--Harvey's discovery in 1628 of the circulation of the blood--consisted of a demonstration that ordinary principles of hydraulic engineering could be sucessfully applied to explain a vital function of the human body.

In the 350 years since Harvey's discovery one after another of the aspects of biology that were originally believed destined to be eternally dependent upon the mystery of vitalism for their explanation has been moved out of the realm of the supernatural by the application of the ordinary laws of physical science. Not only the gross functions of the body organs but many of their details of structure and operation have been found amenable to explanation by the methods of the physicist and chemist. Even the substances that go into the composition of the tissues and cells of living organisms have been found to owe their architecture and properties to the operation of the same physical laws of atomic particles and forces that govern the chemistry of nonliving matter.

In short, the coalescence of the physical and the life sciences has progressed so far that many scientists in both disciplines now suspect that there is no fundamental difference between them--that ultimately all aspects of the structure and behavior of living matter will be explainable in terms of exactly the same fundamental particles and natural laws as those underlying the load-carrying qualities of a bridge, the flight capabilities of a rocket-ship, or the color of the sunset. According to this magnificently unifying concept, there is but one ultimate science.

But if there is only one ultimate science, there must also be only one ultimate supernatural, and that must consist in its totality of the postulate of the original existence of the fundamental particles and natural laws of physical science. All else in biology, as well as in physics and chemistry, must follow. Since living matter is only a different manifestation of the operation of the same particles and natural laws as those governing nonliving matter, there can be no "vital principle," "vital force," or "vitalism" that pertains to the one but not to the other.

These thoughts, of course, are not new. The Greeks formulated many of them. But there is something about the contest in which they arise in the twentieth century that is significantly different from that of previous eras. The thesis of the possible unity of all science emerges today, not just from the contemplative mind of the philosopher, but from the laboratory of the scientist."

Taken from The Machinery of Life,
Dean E. Wooldridge

Science IIIA in the unified science program shifts major emphasis from the interaction of matter and energy in the evolution and development of living organisms to interactions which effect the equilibrium of natural systems.

The mechanisms by which life systems maintain a flow of energy and materials in dynamic equilibrium involve fundamental particles, forces, energies, and natural laws identical to those found in non-living systems.

Since the mechanisms of action and reaction in non-living systems are, generally, less complex than their counterpart in life systems, we shall now focus our attention on interactions in non-living systems.

As a result of these experiences we hope to extend our understanding of natural physical processes to the point where we can more intelligently deal with similar processes in life systems.

MATTER - ENERGY INTERACTIONS IN NATURAL SYSTEMS

QUESTIONS FOR DISCUSSION:

1. What are the innate characteristics, unique to the human species, which account for the emergence of man as the dominant animal species?

2. Is it possible that man may eventually account for all phenomena in nature by the process of scientific inquiry into cause and effect relationships, or, will man always have a need for a belief in the supernatural? In other words, will man always need to ascribe certain phenomena to the existance of forces and events which lie outside the realm of natural cause and effect principles in order to establish a complete concept of the nature of the universe and man's relationship to it?

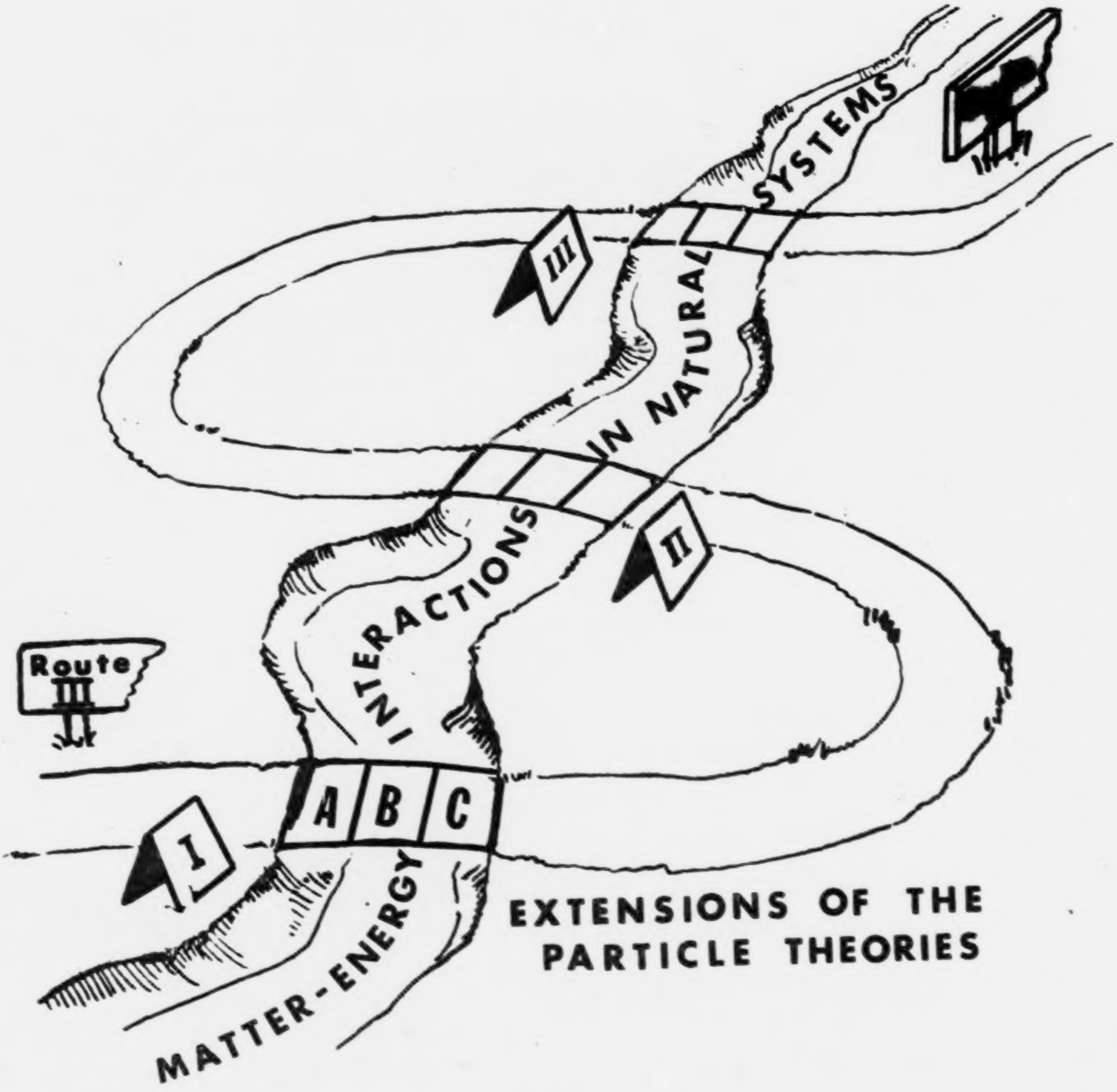
3. It has been said that, "the universe operates largely on the basis of cause and effect relationships". In the broadest sense, what are the causes and what are the effects?

4. Considering the nature of man and the universe in which he lives, how would you define "science"? Do you believe that it is necessary that everyone must become personally involved in the process of science?

5. If living organisms and inanimate objects are composed of the same basic structural material and are subject to the same immutable natural law just what is it that enables some matter to be living?

6. Is man subject to exactly the same set of natural laws designed for the regulation of the impersonal world or can man, because of his uniquesness, evade or alter these laws to more appropriately suit his needs or desires?

SCIENCE IIIA


Route III
I
A
B
C
II
III
MATTER-ENERGY INTERACTIONS IN NATURAL SYSTEMS
EXTENSIONS OF THE PARTICLE THEORIES

A. Interactions in Gases

B. Mole Concept

C. Mechanism of Chemical Reactions

Extensions of the Particle Theories

INTERACTIONS IN GASES

Particle Motion - A Review

Pressure, Temperature, Volume Relationships

Interactions in Gases

PARTICLE MOTION - A REVIEW

Resource Materials

Required Reading: Atoms, Molecules and Chemical Change, 541.2 Gr, pages 66-90

Recommended Reading: The Nature of Solids, Alan Holden, pages 1-20

INTRODUCTION:

Experience with the behavior of molecular substances encountered within a wide range of circumstances has enabled us to formulate a model or theory to explain phenomena which can not be observed directly. Our explanations for such things as the evaporation of liquids, the subliming of solids, the diffusion of gases, and a host of other familiar experiences are based on this theory which we have identified as the Kinetic Molecular Theory. Although, individually, we have developed the ideas inherent in this theory to various levels of sophistication, all of us would consider the following to be basic; (1) Matter is ultimately composed of many tiny particles. (2) The particles have weight and are in continuous motion, hence they possess Kinetic energy. (3) The particles continuously interact with one another and hence possess potential energy.

We have incorporated these basic assumptions in a physical model which was used to represent the behavior of molecular substances as solids, liquids, and gases. The physical model was used to investigate some fundamental ideas about the energy relationships, spacial arrangement, and distribution of velocities among particles representing these various states of matter.

The concept of energy transfer within structures as a result of particle collisions is an extremely important idea, useful in explaining both physical and chemical reactions in matter. Another important idea in our kinetic molecular theory is that the average distance between the particles in a substance increases substantially as the material changes from the solid to the gaseous state but that the particles themselves experience practically no change in density. Since the force with which one body attracts another decreases significantly as the distance between them increases we assume that the potential energy between particles in the gaseous state is practically non-existant. This situation greatly simplifies our model for it assumes that each particle in a gas exists independently of the others except at the time of collision, when transfer of kinetic energy between particles occurs. This situation of course does not actually exist. It represents an "ideal" situation which can be described by statistical mechanics. Since this "ideal" situation is, under most circumstances; very nearly the actual case it represents a practical approach to a study of the mechanics of gases.

During the next few weeks we will be investigating certain phenomena associated with the mechanics of gases. In particular we will be concerned with the effect that changes in temperature and pressure have on the interaction of particles in the gaseous state.

7

QUESTIONS FOR CONSIDERATION:

1. What is the basis for the assumption that the internal energy possessed by any substance is the summation of the kinetic and potential energy of its particles?
   a. What factors influence the magnitude of the kinetic energy possessed by a body?
   b. What factors influence the potential energy?
2. How does the volume of one mole of water at 100°C and 1 atmosphere of pressure compare to the volume of one mole of steam at 100°C? In view of the fact that the temperature is the same how do you account for the difference in volume?
3. How does the internal energy possessed by the molecules of water in these two states compare? Is there any relationship between the change in volume and the change in internal energy? Explain.
4. How is it possible for particles which have the same temperature to possess different kinetic and potential energies?
5. What is the relationship between the heat that a body contains, its temperature, and the kinetic and potential energy possessed by the particles of which it is composed?
6. Describe the relationship which apparently exists between the temperature, pressure, and volume of matter which is in the gaseous state.

PARTICLE MOTION - A REVIEW

I. Development of a Theoretical Model to Account for the Characteristic Behavior of Macrostructures

A. Basic structural units in macrostructures

1. Atoms

2. Molecules

B. The atomic theory

1. Summation of basic assumptions in the atomic theory

2. Purpose of the atomic theory

C. The Kinetic Molecular Theory

1. Summation of basic assumptions in the Kinetic Molecular Theory

2. Physical evidence in support of the ideas inherent in the Kinetic Theory

II. Kinetic Molecular Theory and the Internal Energy of Matter

A. Energy as a physical property

1. Internal energy

2. Conservation of energy in interactions

B. The source of the internal energy possessed by macrostructures

1. Kinetic energy

2. Potential energy

C. Physical characteristics of the various states of matter

1. Solids

2. Liquids

3. Gases

D. Internal energy and the physical state of macrostructures

1. Solids

2. Liquids

3. Gases

Science IIIA
Small Group

QUESTIONS FOR DISCUSSION

The teacher in charge of your small group will moderate the discussion and evaluate your participation in class.

1. What is the difference between a macrostructure and a microstructure?
2. Define an atom.
3. Define a molecule.
4. What is meant by the internal energy of macrostructures?
5. What is the internal energy of macrostructures due to?
6. Under what conditions will a body possess Kinetic Energy?
7. Under what conditions will a body possess Potential Energy?
8. What types of forces influence the Potential Energy of a body?
9. Can the PE of a body ever be zero? Explain.
10. Can the KE of a body ever be zero? Explain.
11. Under what conditions may the PE energy of a body be increased to zero?
12. Under what conditions would the PE of a body be positive?
13. Under what conditions will a body which experiences interactions, resulting in attraction, have its potential energy increased?
14. Under what conditions will a body which experiences interactions, resulting in repulsion, have its PE increased?
15. How does the internal energy of a substance in the solid state differ from the internal energy of the material as a liquid?
16. Explain why the internal energy of a particular type of matter is considered to be a physical property.
17. What happens to the internal energy of a gas when its temperature is increased and at the same time, the volume of the container is enlarged to confine the expanding gas with no change in pressure?
18. What happens to the internal energy of a gas when its volume is reduced, assuming that its temperature remains constant?
19. On the basis of your understanding of the Kinetic Molecular Theory, define the difference between a solid and a gas.
20. Is it possible to increase the KE of a body without also increasing its PE? Explain.

THE SLIDE RULE

The slide rule consists of three parts: (1) the body; (2) the slide; (3) the cursor, or indicator, with its hairline. The scales on the body and the slide are arranged to work together in solving problems, and each scale is named by a letter or other symbol. The hair line on the indicator is used to help read the scales and adjust the slide.

The scales to be used and the calculations that can be done on the slide rule are:

a. C and D scales - multiply
b. C and D scales - divide
c. C and CI scales - find reciprocals
d. A and D or B and C scales - squares and squares roots
e. K and D scales - cubes and cube roots

The scale labeled C and the scale labeled D are exactly alike. The total length of these scales has been separated into many parts by fine lines called "graduations".

If these scales were long enough the total length of each would be separated into 1000 parts. First they would be separated into 10 parts. Then each of these would be again separated into 10 parts, making a total of 1000 small parts. On the C and D scales the parts are not all equal. They are longer at the left-hand end than on the right-hand end. At the left end there is enough space to print all of the fine graduations. Near the right end of a short rule there is not enough room to print all of the graduations. In using the rule, however, you soon learn to imagine that the lines are all there, and to use the hairline on the indicator to help you locate where they should be.

The marks which first separate the scale into 10 parts are called the "primary" graduations. The marks which divide each of the 10 parts into tenths are called the "secondary" graduations. Both the C and D scales have the "primary" and "secondary" graduation printed on the scale. The graduations which divide the scale into 1000 parts, or "tertiary" graduations are not all printed on the scale. The number 1 at the far left of each scale is called the "left index" and the number 1 at the far right of each scale is called the "right index".

The numbers printed on the scales tell you only the "digits" the number contains. They do not show the location of the decimal point.

PROBLEMS: Use the hairline on your slide rule indicator to locate the following numbers on the C and D scale of your slide rule.

195 119 110 101 223 206 465 402 694 987 3560 198000

The A scale is a contraction of the D scale. The A scale represents the D scale shrunk to half its former length and printed twice on the same line.

The K scale is also a contraction of the D scale. The K scale represents the D scale shrunk to one third its former length and printed three times on the same line.

The CI scale is the same as the C scale but reads from right to left.

The B scale is the same as the A scale.

SCIENTIFIC NOTATION

Measurements made by scientists, like all measurements, are approximate. Measurements or calculations made with a slide rule are always approximations. A slide rule will ususally give approximations to three significant digits, or if only the left-hand portion of the rule is used, to four significant digits.

A significant digit is a digit obtained by measurement. Digits other than zero are always significant. Zero is significant if it is between two other digits, as in 1.09; or if it is written to the right of the decimal point as in 1.10. Zero is not significant if it is used merely to show the position of the decimal point, as in .0015 or 45,000.

Answers to computations can never be more accurate than the numbers used in the computation. An answer to a problem can never contain more than the least number of significant digits in the numbers used. All numbers to be used in slide rule computations must be rounded off to three or four significant digits.

REWRITING NUMBERS IN STANDARD FORM

The Standard Form of a number may be represented as $A \times 10^n$, where A is a number beteen 1 and 10, and n is nay number. So, to express a number in the standard form, you must determine A and n. The number A must contain all the known significant digits in the original number.

Suppose you want to write 93,000,000 in the standard form. You know that two digits are significant, 9 and 3. So the value of A is 9.3. To find the value of n, place (or imagine) a caret after the first significant digit in the original number; that is 9‸3,000,000. Then count the number of placed between the caret and the decimal point (which is not written in the case of whole numbers). There are seven such places in this number so n is 7. The standard form of 93,000,000 is 9.3×10^7.

To find the standard form of .00247 first write .002‸47. The value of A is 2.47. In counting the number of places between the carat and the decimal point you move to the left which is the negative direction so that n is -3. The standard form of the number is 2.47×10^{-3}.

PROBLEMS: Write the following in the standard form.

1. 6.54
2. 73.5
3. .245
4. .0123
5. 34,500,000
6. 879,000,000
7. 2,456,987
8. 123,000
9. .00135
10. .000789
11. .00000012
12. .000045867

Write each of the following in the decimal form.

13. 10^3
14. 10^6
15. 10^{-2}
16. 10^{-4}
17. 1.23×10
18. 4.56×10^5
19. 7.21×10^2
20. 8.36×10^7
21. 9.87×10^{-5}
22. 1.23×10^{-1}
23. 9.87×10^{-3}
24. 5.34×10^{-7}

TO MULTIPLY USING THE SLIDE RULE

1. Find the multiplicand on the D scale.
2. Move either the right of the left index (1) on the C scale directly over the multiplicand. (Use the hairline to line up the numbers.)
3. Move the cursor so the hairline is on the multiplier on the scale.
4. Read the product directly below the multiplier on the D scale.
5. Determine the position of the decimal point by using powers of 10, scientific notation.

EXAMPLES:

15 x 3.7 = 55.5

280 x 0.34 = 95.2

753 x 89.1 = 67.100

.0215 x 3.79 = .0815

9.54 x 16.7 =159.3

2.9 x 3.4 x 7.5 =73.9

343 x 91.5 x .00532 = 167

13.5 x 709 x .567 x .97 =5260

17

PROBLEMS:

2.56 x 1.6 =

3.5 x 2.8

7 x 1.4 =

9 x 2.1 =

6 x 75 =

3.1 x 4.1 =

1.8 x 8 =

.161 x 9 =

131 x 8 =

1.15 x 9 =

520 x 3.5 =

981 x .0043 =

.000166 x .705 =

.0196 x .29 =

2560 x .0026 =

.715 x .0137 =

2.8 x 5.1 x 96 =

2.5 x 605 x 94 =

2.55 x 3.1416 x 108 =

.00195 x 195 x 350 =

TO DIVIDE USING THE SLIDE RULE

1. Find the dividend on the D scale.
2. Move the cursor so that the divisor in the C scale is directly over the dividend of the D scale. (Use the hairline to line up the numbers.)
3. The quotient is on the D scale directly below the right or left index (1) on the C scale.
4. Determine the position of the decimal point using powers of 10, scientific notation.

EXAMPLES:

83 ÷ 7 = 11.86

75 ÷ 92 = .815

137 ÷ 513 = .267

17.3 ÷ 231 = .0749

8570 ÷ .0219 = 391,000

PROBLEMS:

6.4 ÷ 2 =

940 ÷ 3.5 =

370 ÷ 140 =

255 ÷ 13 =

.00692 ÷ .00085 =

3500 ÷ .063 =

.008 ÷ 852 =

.055 ÷ 852 =

1.68 ÷ 12 =

1080 ÷ 8 =

10.04 ÷ 2 =

2.01 ÷ 52 =

4990 ÷ 307 =

387 ÷ 55.5 =

.000760 ÷ .051 =

405 ÷ .0215 =

195 ÷ 1800 =

.0409 ÷ 161 =

.086 ÷ 2 =

115 ÷ 4450 =

COMBINED OPERATIONS (MULTIPLICATION AND DIVISION)

EXAMPLES:

$$\frac{27 \times 43}{19} = 61.1$$

$$\frac{.691 \times 34.7 \times .0561}{91{,}500} = .0000147 \text{ or } 1.47 \times 10^{-5}$$

$$\frac{5.17 \times 1.25 \times 9.33}{4.3 \times 6.77} = 2.07$$

$$\frac{19.45 \times 7.86 \times 361 \times 64.4}{32.6 \times 9.74} = 11{,}190$$

PROBLEMS:

$$\frac{160 \times 75}{28.5 \times 22} =$$

$$\frac{550 \times 82}{20 \times 22} =$$

$$\frac{156 \times 3.36}{72.5 \times 12.8} =$$

$$\frac{.008 \times 3}{.012 \times 6} =$$

$$\frac{143.5 \times 2.3 \times 2}{82 \times 56} =$$

$$\frac{.0063 \times .0495}{.000012 \times 18} =$$

$$\frac{160 \times 54 \times .0092}{92.8 \times 45 \times .986} =$$

$$\frac{360 \times 458 \times 95}{92 \times 13 \times .00012} =$$

$$\frac{20}{375 \times .065 \times 980} =$$

$$\frac{.000655}{41 \times 80 \times 35} =$$

SLIDE RULE REVIEW

I. Basic Mathematical Concepts

   A. Significant digits

   B. Scientific Notation

   C. Standard form of a number

   D. Laws of exponents

      1. Multiplication

      2. Division

II. Slide Rule Manipulation

   A. Parts of the slide rule

   B. Scale structure (C and D)

      1. Indices

      2. Graduations

      3. Significant digits and doubtful figures

   C. Slide rule settings

   D. Decimal point location

   E. Multiplication

   F. Division

   G. Combined operations

Name________________________
Science IIIA Hour__________
Date Due______________________

Exercise

SLIDE RULE REVIEW

Estimate the answer and use the slide rule to multiply the following:

1. 3.5 x 2.8 =
2. 7 x 1.4 =
3. .161 x 9 =
4. 981 x .0043 =
5. 2.8 x 5.1 x 96 =
6. .00195 x 195 x 350 =

Estimate the answer and use the slide rule to divide the following:

1. 6.4 ÷ 2 =
2. 255 ÷ 13 =
3. .008 ÷ 852 =
4. 405 ÷ .0215 =
5. .00692 ÷ .00085 =
6. .0086 ÷ 45,700 =

Estimate the answer and use the slide rule to evaluate the following:

1. $\frac{434 \times 7.3}{37} =$
2. $\frac{727 \times 82.5}{51.3} =$
3. $\frac{739 \times 81}{5.4} =$
4. $\frac{9.21 \times 5.66}{846} =$
5. $\frac{4 \times 300 \times 100}{7 \times .6} =$
6. $\frac{101 \times 17}{4 \times 6} =$

Exercise

Name____________________
Science IIIA Hour_______
Date Due__________________

COMBINED OPERATIONS

Use the slide rule to evaluate each of the following. Express the answer with the proper number of digits and the decimal point in the correct position. Be sure to estimate the answer before doing the slide rule operation.

1. $\frac{4 \times 500}{3.1} =$

2. $\frac{20.4 \times 5.2}{2.1} =$

3. $\frac{2.4 \times 3.6}{3.1} =$

4. $\frac{32.1 \times 14}{1.68} =$

5. $\frac{9.2 \times 4.6}{49} =$

6. $\frac{14 \times 12}{170} =$

7. $\frac{583 \times 33}{30.7} =$

8. $\frac{54.1 \times 12.14}{276} =$

9. $\frac{49.2 \times 3.14}{67.7 \times 15.1} =$

10. $\frac{2000 \times 80{,}000}{60{,}000{,}000} =$

11. $\frac{323 \times 112 \times 48.7}{5.9 \times 505} =$

12. $\frac{.74 \times 29{,}430 \times .0462}{.00059 \times 303} =$

13. $\frac{23}{291 \times .024 \times 684} =$

14. $\frac{41 \times 6999 \times .723 \times .000672}{186{,}000 \times 8.36 \times 5} =$

Interactions in Gases

Laboratory Problem

MOLECULAR THEORY AND THE PRESSURE, TEMPERATURE, VOLUME RELATIONSHIP IN GASES

INTRODUCTION:

The distance between the particles which compose matter in the gaseous state is so great, compared to the diameter of the particles, that the potential energy of gases is considered to be zero. The internal energy possessed by a gas is assumed to be equal to the kinetic energy of its individual particles.

Our Kinetic Molecular Theory suggests that the individual particles within a gas at any particular temperature and pressure possess the same average kinetic energy. This implies that gaseous particles of the same weight travel with the same average rate of motion, although the direction of their motion is random. The temperature of the gas is a measure of this average rate of particle motion.

The pressure of a gas is a measure of the force per unit area exerted by the individual gas molecules in collision with the side wall of the container. The magnitude of the pressure depends upon the weight of the particle and the speed with which it travels. Thus the kinetic energy of a gas may be described indirectly in terms of its pressure and temperature.

We know that the volume of any gas may be changed without increasing or decreasing the number of individual particles it contains. Such changes in volume occur as a result of changes in temperature and pressure. For this reason it is not possible to describe or measure the quantity of matter in a given volume of gaseous matter without knowing the pressure and temperature of the gas particles confined.

PROBLEM:

1. What is the quantitative relationship between the volume of a gas and its pressure when temperature is constant?
2. What is the quantitative relationship between the volume of a gas and its temperature when the pressure is held constant?

How could our macromolecular model be used to provide experimental data characteristic of:

1. a variable volume - pressure relationship with temperature constant?
2. a variable volume - temperature relationship with pressure constant?

Design an experimental procedure which would provide data for these conditions. Represent the data in both tabular and graphic form.

The "conclusion" of the laboratory report on this problem should include a mathematical statement (equation) representing the volume - pressure relationship and the volume - temperature relationship illustrated by the graphic interpretation of the data.

QUESTIONS:

1. What is the relationship between the volume of an ideal gas and its pressure, with temperature constant?

2. What is the relationship between the volume of an ideal gas and its temperature, with pressure constant?

3. According to the volume - pressure relationship suggested by the experimental data, what pressure would be required to reduce the volume of a gas to zero? Is this possible?

4. According to the volume - temperature relationship suggested by the experimental data , what would the volume of a gas be when its temperature equaled zero?

   Is this actually possible?

5. What do questions 3 and 4 suggest about the difference between the properties of an "ideal gas" and those of actual gases?

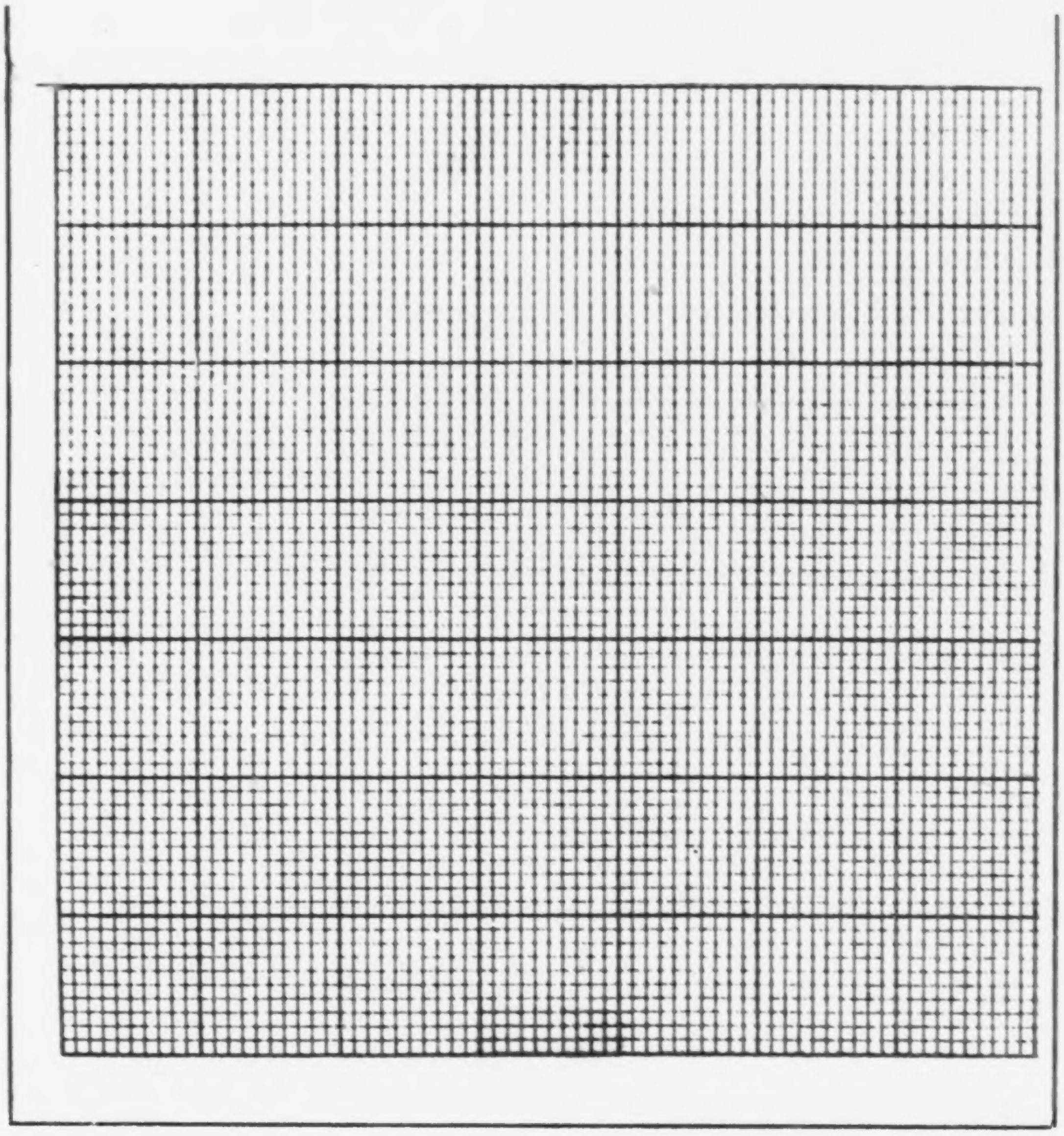
Experimental Data:

VOLUME - TEMPERATURE RELATIONSHIP
(Pressure Constant)

Volume	Temperature	Pressure	

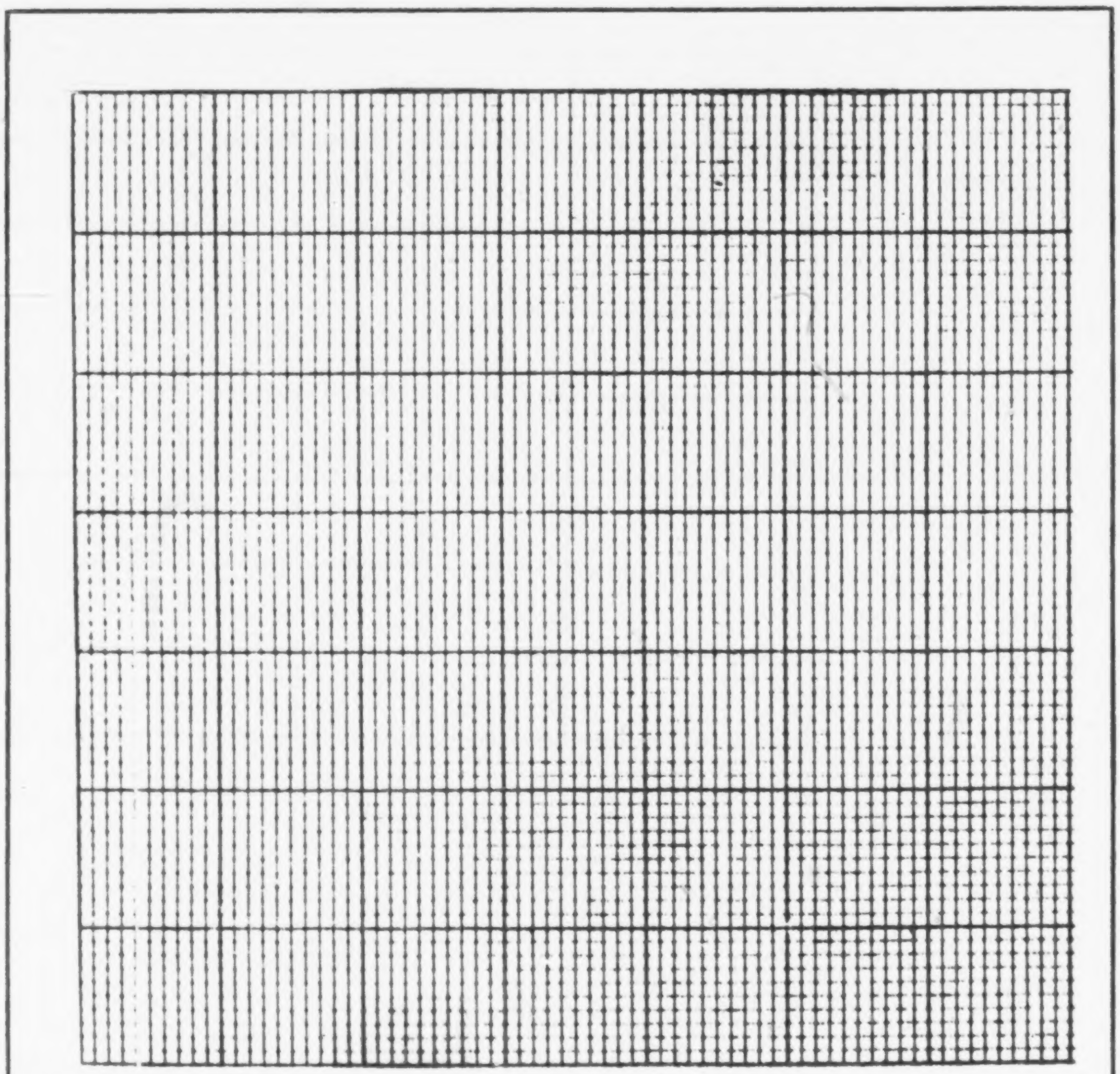
VOLUME - PRESSURE RELATIONSHIP
(Temperature Constant)

Volume	Pressure			Temperature	



Volume - Pressure
Relationship
(temperature constant)

Volume - Temperature
Relationship
(pressure constant)



EXTENSIONS OF THE PARTICLE THEORIES

Interactions in Gases

Resource Material

PRESSURE, TEMPERATURE, VOLUME RELATIONSHIPS

Required Reading:	Modern Chemistry, Chapter 9, pages 134-144
Recommended Reading:	Matter, Earth, and Sky, Chapter 8, pages 193-212

QUESTIONS FOR CONSIDERATION:

1. In what ways do the interactions of "real" gases differ from those theorized for an "ideal" gas?

   In view of this what are the limitations of the "ideal" gas law?

2. How do you account for the fact that the coefficients of expansion for matter in the solid and liquid states are different for different materials, but, all matter in the gaseous state has the same coefficient of expansion?

3. Describe the changes which occur in the internal energy of a given volume of a gas when the pressure on that volume is doubled and it experiences a temperature change from 273°K to 273°C.

4. Explain, in terms of the internal energy of gases, why the partial pressure exerted by a gas in a gaseous mixture is directly proportional to the ratio of the volume of that partiuclar gas to the total volume of the gaseous mixture.

5. Explain what partial pressure corrections would be required in order to determine the volume of a gas being generated under the following conditions:
   a. gas measured over mercury, level inside the eudiometer the same as that outside -
   b. gas measured over mercury, level inside eudiometer higher than that outside -
   c. gas measured over water, level inside eudiometer same as that outside -
   d. gas measured over water, level inside eudiometer higher than outside -

PRESSURE, TEMPERATURE, VOLUME RELATIONSHIPS

I. Pressure, volume relationship

$pV = "k"$

II. Temperature, volume relationship

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

A. Coefficient of volume expansion for gases

B. Temperature scales and conversions

1. Celsius
2. Fahrenheit
3. Kelvin (absolute)

III. "Standard Conditions" of pressure and temperature (STP)

A. Common equivalent values for standard pressure

B. Values for standard temperature

Problem Exercise

Name ______________________

Science IIIA Hour _____

Date ______________________

KINETIC MOLECULAR THEORY OF GASES

1. A given mass of hydrogen chloride gas occupies a volume of 50 ml at 20° C. Determine its volume at 127° C, pressure remaining constant.

2. A quantity of carbon dioxide gas occupies a volume of 100 ml at 0°C. What volume will the gas occupy at a temperature of 50°C, the pressure remaining constant?

3. A given mass of gas occupies 150 cubic feet at a temperature of 27°C. At what temperature, pressure remaining constant, will this mass of gas occupy a volume of 100 cubic feet?

4. A mass of hydrogen occupies 100 ml at a temperature of -73°C. At what temperature will this same mass occupy 150 ml, the pressure remaining constant?

5. What volume will 40 ml of nitrogen, measured at 15°C and 780 mm of mercury, occupy at standard conditions (STP)?

6. Five liters of a gas, measured at standard conditions (STP), are heated to 100°C and subjected to a pressure of 800 mm. What is the volume occupied by the gas at the new conditions?

7. Seventy-five cubic feet of hydrogen, measured at 20°C and 750 mm pressure, are subjected to a pressure of 800 mm. At this pressure what must the temperature of the gas be if its new volume is to be 100 cubic feet?

8. A mass of a gas occupies 100 ml when measured at 50°C and a pressure of 730 mm. What pressure must be applied to make the gas volume 75 ml at a temperature of 27°C?

IV. Ideal Gases

A. Characteristic Properties of an "Ideal Gas"

1. Physical Structure

2. Internal Energy

B. Combined Gas Law for "Ideal Gases"

$$\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$$

1. Derivation

2. Techniques in the Use of the Combined Gas Law

V. Partial Pressures

A. Interactions in Gaseous Mixtures

B. Pressure Corrections in Calculating Volumes of Gases

1. Collection Over Mercury

2. Collection Over Water

Problem Exercise

Name ______________________________

Science IIIA Hour ______

Date ______________________________

PARTIAL PRESSURES IN GASES

1. In an experiment 35.0 ml of hydrogen were collected in a eudiometer over mercury. The mercury level inside the eudiometer was 40. mm higher than that outside. The temperature was 25° C and the barometric pressure was 740.0 mm. Correct the volume of hydrogen to S.T.P.

2. A gas collected over mercury in an inverted graduated cylinder occupies 60.0 ml. The mercury level inside the cylinder is 25 mm higher than that outside. Temperature: 20.°C; barometer reading: 715 mm. Correct the volume of gas to S.T.P.

3. Hydrogen is collected by water displacement in a eudiometer. Gas volume, 25.0 ml; liquid levels inside and outside the eudiometer are the same; temperature, 17° C; barometer reading, 720.0 mm. Correct the volume to that of dry gas at S.T.P.

4. Some nitrogen is collected over water in gas-measuring tube. Gas volume, 45.0 ml; liquid levels inside and outside the gas-measuring tube are the same; temperature, 23°C; barometer reading, 732.0 mm. Correct the volume to that of dry gas at S.T.P.

5. A volume of 50.0 ml of oxygen is collected over water. The water level inside the eudiometer is 65 mm higher than that outside. Temperature, 25° C; barometer reading 727.0 mm. Correct the volume to that of dry gas at S.T.P.

6. At 18°C and 745.0 mm pressure, 12.0 ml of hydrogen are collected over water. The liquid level inside the gas-measuring tube is 95 mm higher than that outside. Correct the volume to that of dry gas at S.T.P.

7. A sample of 100 ml of dry gas, measured at 20°C and 750 mm, occupies a volume of 105 ml when collected over water at 25°C and 750 mm. Calculate the vapor pressure of water at 25° C.

8. A gaseous mixture of oxygen and carbon dioxide occupying 480 cm^3, was stored over water at 1.2 atmospheres pressure and 40°C. The partial pressure of the oxygen was 140 mm Hg. Calculate the volume that the carbon dioxide would occupy at S.T.P.

TABLE--PRESSURE OF WATER VAPOR IN MILLIMETERS OF MERCURY

°C	mm	°C	mm	°C	mm	°C	mm
0.0	4.6	17.5	15.0	22.5	20.4	30.0	31.8
5.0	6.5	18.0	15.5	23.0	21.1	35.0	42.2
7.5	7.8	18.5	16.0	23.5	21.7	40.0	55.3
10.0	9.2	19.0	16.5	24.0	22.4	50.0	92.5
12.5	10.8	19.5	17.0	24.5	23.1	60.0	149.4
15.0	12.8	20.0	17.5	25.0	23.8	70.0	233.7
15.5	13.2	20.5	18.1	26.0	25.2	80.0	355.1
16.0	13.6	21.0	18.7	27.0	26.7	90.0	525.8
16.5	14.0	21.5	19.2	28.0	28.3	95.0	633.9
17.0	14.5	22.0	19.8	29.0	30.0	100.0	760.0

INTERACTIONS IN GASES

I. Summation of Basic Assumptions in Atomic Theory

II. Summation of Basic Assumptions in the Kinetic Molecular Theory

III. Internal Energy of Matter (What is the source of internal energy?)

  A. Kinetic Energy

  B. Potential Energy

    1. For bodies which experience a resultant force of attraction

    2. For bodies which experience a resultant force of repulsion

IV. Difference Between the Internal Energy of Solid - Liquid - Gas

V. Pressure - Volume Relationship for Gases Combined Ideal Gas Law

VI. Characteristics of an "Ideal Gas"

VII. Partial Pressure

VIII. Factors to Consider in the Measurement of Gas Volumes

IX. Systems Units and Definitions

Extension of the Particle Theories

MOLE CONCEPT

The Development and Implications of the Avogadro Hypothesis

Significance of the Avogadro Hypothesis in Contemporary Science

Ideal Gas Law Equation

Mole Concept

Resource Material

THE DEVELOPMENT AND IMPLICATIONS OF THE AVOGADRO HYPOTHESIS

Required Reading: Atoms, Molecules and Chemical Change, 541.2 G89a(L), Molecular Formulas and the Atomic Weight Scale, pages 95-104

Recommended Reading: The Development of Modern Chemistry, by Aaron J. Ihde, pages 116-122 and pages 226-230.

QUESTIONS FOR CONSIDERATION:

1. Discuss the interrelation of combining weights, molecular formulas and relative atomic weights.

2. What problem exists in the relationship in Question 1 and what was John Dalton's solution to the problem?

3. John Dalton had three important reasons why he rejected the Law of Combining Volumes. One was based on theoretical considerations and two on experimental facts. Discuss these three reasons.

4. Why was John Dalton so violently opposed to Avogadro's suggestion that molecules of the elementary gases are diatomic?

5. How did Avogadro come to the conclusion that the elementary gases are diatomic rather then triatomic or tetratomic?

6. Why did Berzeluis reject the idea of diatomic molecules for elementary gases?

Mole Concept

THE DEVELOPMENT AND IMPLICATIONS OF THE AVOGADRO HYPOTHESIS

I. Discovery of Some Basic Laws of Interactions

   A. Carl Wilhelm Scheele (1742-1786)

   B. Joseph Priestley (1733-1804)

   C. Antoine Laurent Lavoisier (1743-1794)

   D. Claude Louis Berthollet (1748-1822)

   E. Joseph Louis Proust (1754-1826)

II. The Atomic Theory

A. John Dalton (1766-1844)

1. Fundamental ideas

2. Evidence for existence of atoms

3. A perplexing triangular relationship

B. Jons Jakob Berzelius (1779-1848)

III. Law of Combining Volumes

A. Joseph Louis Gay-Lussac (1778-1850)

B. A proof and a problem

C. Dalton's objections

IV. Avogadro's Hypothesis -- The Perfect Solution

A. Amadeo Avogadro (1776-1856)

B. Rejection of the hypothesis

V. A period of chaos (1811-1858)

VI. A return to Avogadro

A. Stanislao Cannizzaro (1826-1910)

B. The Karlsruhe Congress - 1860

C. Julius Lothar Meyer (1830-1895)

Mole Concept

Resource Material

SIGNIFICANCE OF THE AVOGADRO HYPOTHESIS IN CONTEMPORARY SCIENCE
and the
IDEAL GAS LAW

Required Reading: Atoms, Molecules and Chemical Change, 541.2 G89a (L), Molecular Formulas and the Atomic Weight Scale, pages 104-109

Recommended Reading: The Mole Concept in Chemistry, 541.2 K47m (L), Introduction and Gases, pages 1-21 and Avogadro's Number, pages 91-99

QUESTIONS FOR CONSIDERATION:

1. The definition of the mole was derived from two previously existing units. What are these units?

2. The term "mole", when applied to any substance, refers to that weight which is represented by the formula of the substance. This means that in most cases the term "gram-atom" and "mole" may be used synonymously. Discuss one case where this cannot be done.

3. Discuss the advantages of the Ideal Gas Law in terms of:

   a. efficiency -

   b. its usefulness in operating with mole related quantities -

4. If standard temperature had been defined as 20°C instead of 0°C, how would the molar volume have been affected?

5. The much quoted molar volume, 22.414 l at STP, actually is not constant. It varies from 22.09 l for ammonia to 22.426 l for helium. Explain the inconstancy of this "constant".

6. The mole is often called the chemist's expression of amount. Why is the mole much more significant as a weight unit (in chemical reactions) than a gram?

Mole Concept

SIGNIFICANCE OF THE AVOGADRO HYPOTHESIS IN CONTEMPORARY SCIENCE

I. Development of Fundamental Relationships

II. Definitions

- A. Compound
- B. Element
- C. Gram molecular volume

III. Experimental Determination of the Avogadro Number

A. Sedimentation Data (Brownian Motion)

B. Electrolysis data

C. Crystal Structure Data

D. Radioactivity Data

E. Surface Area of Monomolecular Films

Laboratory Problem

THE SIZE OF A MOLECULE AND THE AVOGADRO NUMBER

INTRODUCTION:

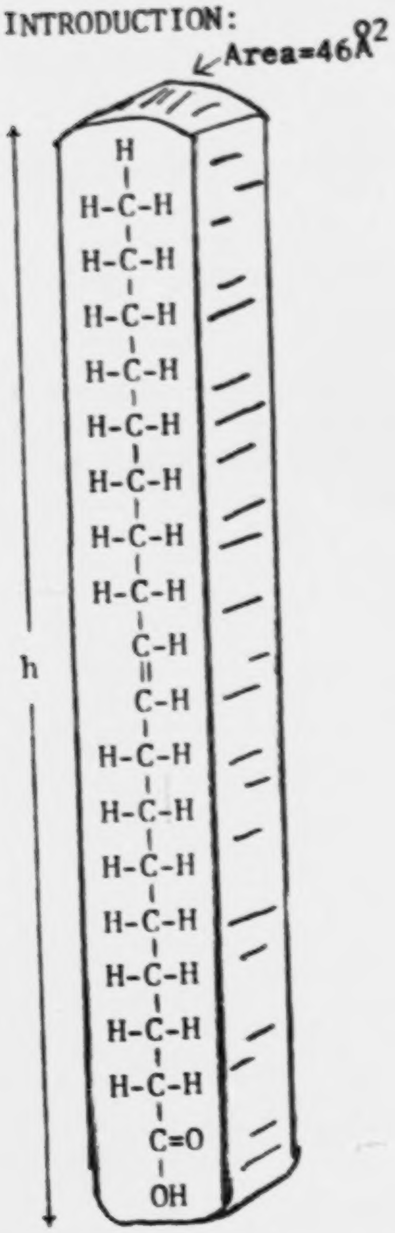


Figure 1

Even though single molecules may be composed of a half million or more atoms, they are still too small for their size to be measured by any direct methods. The electron microscope makes it possible to photograph only the largest molecules. However, certain indirect methods will give us a fair idea of the dimensions or "order of magnitude" of the molecule. (The "Order of Magnitude" refers to a number being correct to the nearest power of 10.) If, then, a resonable shape for the molecule is assumed, it is possible to determine experimentally the Avogadro Number.

Calculations in this experiment depend on the unique properties of the molecule chosen. It must have a molecular structure with distinctly different ends (one of them water soluble) so that it will stand on end when placed on water. This allows for the formation of a monolayer or film of molecules one molecule thick. The oleic acid used in this experiment has such a structure. Oleic acid has the formula $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ and the structure shown in Figure 1. The height of the molecule standing on end in the water is considered to be the diameter of the molecule. This height can be calculated since it is assumed the oleic acid placed on the water spreads out to form a geometric cylinder whose base area can be measured directly and whose height is the diameter of the molecule. If pure oleic acid were dropped on the surface of water, the drop would spread out to cover many square meters if not stopped by the sides of a container. To get a layer one molecule thick within the confines of the container the oleic acid is diluted with gasoline. The distance across the monolayer can be measured with a metric ruler. In order to calculate the volume of pure oleic acid placed on the surface of the water as one drop of oleic acid solution is placed there, it is necessary to determine experimentally the number of drops of oleic acid solution per cc of the solution which the pipette is capable of dropping. The volume of one drop of solution used with the dilution ratio (1cc of pure oleic acid to 700 cc of oleic acid solution) permits the calculation of the actual volume of pure oleic acid placed on the water as one drop of the solution is placed there. This is the volume of the surface layer which is essentially spread out in the shape of a cylinder, the height of which is the size of one molecule.

PROBLEM:

The density of pure liquid oleic acid is .895 g/cc. Use the given information and the techniques suggested in the introduction to determine the height of the oleic acid molecule in centimeters. Calculate the Avogadro Number using your experimentally measured molecule height with each of the following assumptions of molecule shape. The assumptions increase in validity from a to b to c.

a. assume the molecules are cubes with an edge equal to the measured height.

b. assume the molecules are rectangular solids with a width equal to one half the measured height.

c. assume the molecules are rectangular solids with a base area of 46Å^2 per molecule and a height as measured experimentally. (The value of 46Å^2 is supported by considerable indirect evidence and is given in reference books as the most valid base area.)

Problem Exercise

Name ______________________

Science IIIA Hour _____ 46

Date ______________________

THE GRAM ATOMIC WEIGHT

The gram atomic weight is a weight unit defined as a weight in grams of an element equal to the atomic weight. The number of atoms in a gram atomic weight is the Avogadro Number 6.02252×10^{23}. For practical use the words gram atomic weight are shortened to gram atom and abbreviated g atom. For practical use, also, in English speaking countries, the units of pound atom and ton atom have been devised. A pound atom or ton atom is the weight in pounds or tons equal to the atomic weight of an element.

PROBLEMS:

1. What is the weight, in grams, of two gram atoms of sulfur?

2. How many grams of nitrogen are there in .025 g atoms of nitrogen?

3. How many g atoms of potassium are represented by 2×10^{26} atoms of potassium?

4. How many atoms of carbon are there in a block of carbon weighing 110 g?

5. Calculate the weight in grams of 4.2×10^{20} atoms of magnesium.

6. How many g atoms of carbon would it take to have the same weight as 1.2 g atoms of sodium?

7. How many atoms of silver are there in a piece of silver weighing .5 kg?

8. A mixture of zinc and sulfur contained .2 g atom of each element. What was the weight of the mixture?

9. How many atoms are there in 10^{-5} g of calcium?

10. Calculate the weight in grams of one atom of zinc.

11. A pencil mark 1.000 cm long, .050 cm wide and .010 cm thick is made with a soft lead. Assuming that the pencil mark is made of pure carbon and that the density of carbon is 2 grams per cubic centimeter, how many carbon atoms are there in the pencil mark?

ATOMIC WEIGHTS

S = 32
N = 14
K = 39
C = 12
Ca = 40

Mg = 24
Na = 23
Ag = 108
Zn = 65

Problem Assignment

Name ______________________________

Science IIIA Hour _____

Date ______________________________

THE MOLE

The gram molecular weight is a weight unit defined as a weight in grams of a compound equal to the molecular weight. The words gram molecular weight are shortened to mole and the number of molecules to the mole is the Avogadro Number. For gaseous compounds the volume of one mole at STP is 22.414 l for an ideal gas. The pound mole and ton mole are practical units used in English speaking countries. A pound mole or ton mole is the weight in pounds or tons equal to the molecular weight of the compound.

PROBLEMS:

1. Calculate the number of grams in 3 moles of H_2SO_4.

2. What is the weight in grams of 1.9 moles of $Al_2(CrO_4)_3$?

3. How many moles are there in 4.1 g of Na_2O?

4. How many molecules are there in 30 g of CO?

5. Calculate the weight in grams of 8.00×10^{23} molecules of CH_4?

6. What is the weight in grams of one molecule of oxygen?

7. A .03 mole sample of a compound weighed 2.28 g. Calculate the molecular weight of the compound.

8. How many pounds are there in 2.5 pound moles of K_2CO_3?

9. A company buys 400 tons of sodium chloride. How many ton moles is this?

10. Three liters of a dry gas weigh 8.58 g at STP. Calculate the molecular weight of the gas.

11. What volume will 100 g of fluorine gas occupy at STP.

12. How many molecules are there in 90 liters of N_2O gas measured at STP?

ATOMIC WEIGHTS

H = 1

S = 32

O = 16

Al = 27

Cr = 52

Na = 23

C = 12

K = 39

Cl = 35.5

F = 19

N = 14

Problem Exercise

Name ______________________

Science IIIA Hour _____ 50

Date ______________________

WEIGHT CALCULATION

1. How many grams of oxygen are there in 125 g of HgO?

2. How many grams of oxygen are there in 150 g of As_2O_5?

3. How many gram atoms of oxygen are there in 3 moles of Al_2O_3?

4. How many moles of $Cr_2(SO_4)_3$ will contain 4 g atoms of oxygen?

5. How many gram atoms of antimony are there in 300 grams of Sb_2O_3?

6. How many grams of iron are there in 5.00 gram formula weights of Fe_2O_3?

7. How many moles of CH_4 are there in 180 g of CH_4?

8. How many moles of H_2S will contain 160 g of sulfur?

9. How many mole of $NaClO_3$ will contain 4 gram atoms of oxygen?

10. How many grams of oxygen are there in .2 gram formula weight of $NaMnO_4$?

11. How many grams of oxygen are there in 65 g of CaO?

12. What weight of K_2O will contain 60 g of oxygen?

13. How many grams of Fe_3O_4 will contain 128 g of oxygen?

ATOMIC WEIGHTS

Hg = 201

O = 16

As = 75

Al = 27

Cr = 52

Na = 23

Mn = 55

K = 39

S = 32

Sb = 122

Fe = 56

C = 12

H = 1

Cl = 35.5

Ca = 40

Laboratory Problem

THE MOLAR VOLUME OF A GAS

PROBLEM:

A balance is to be prepared so that a piece of calcium metal (.04 g - .07 g) may be weighed rapidly. Using the replacement action of calcium with water determine experimentally the molar volume of a gas.

DATA:

SUMMARY QUESTIONS:

1. Write the equation for the replacement reaction.
2. Calculate the % of error.
3. Discuss the sources of error in this experiment. For each source of error mentioned, indicate the effect which this source has on the value for the experimentally determined molar volume.

EXTENSIONS OF THE PARTICLE THEORIES

Mole Concept

IDEAL GAS LAW EQUATION

I. Derivation of the Ideal Gas Law Equation

II. Advantages of the Ideal Gas Law Equation

EXTENSIONS OF THE PARTIAL PRESSURE CONCEPT

I. Dalton's Law of Partial Pressue

II. Proportionality Law

III. The Mole Fraction

Problem Exercise

Name ______________________________

Science IIIA Hour ______

Date ___________________________

THE IDEAL GAS LAW EQUATION

$PV = nRT$

1. What volume will 85 g of SO_2 gas occupy at 30°C and 700 mm?

2. The oxygen gas in a 3 liter steel cylinder at 20°C was under a pressure of 50 atm. How many moles of O_2 were in the cylinder?

3. What pressure in atmospheres, will 25 g of He gas exert when placed in a 4.25 liter steel cylinder at 100°C?

4. Calculate the weight in grams of the pure CH_4 gas contained in a 40 liter cylinder at 25°C under a pressure of 3 atm.

5. Calculate the weight in grams of 250 liters of CO gas at 40°C and 750 mm.

6. Calculate the volume in liters occupied by 370 g of H_2S gas at 32°C and 800mm.

7. A 15 liter cylinder contains 11.5 moles of neon gas at 30°C. What is the pressure in atmospheres of the neon gas?

8. How many grams of nitrogen are there in 22.4 liters of NO_2 gas at 2 atm. and 546°K?

9. A cylinder containing 74 g of NH_3 at 100°C shows a pressure of 5 atm. What is the volume of the cylinder in liters?

10. A storage tank contains 10 liters of dry hydrogen gas at 33°C and 40 atm. pressure. Calculate the weight in kilograms of the hydrogen gas in the tank.

11. A volume of 20 liters of CO_2 gas measured at 100°C and 5 atm. will contain how many molecules?

12. A volume of 60 cc of dry gaseous compound, measured at 22°C and 742 mm. weighed .820 g. Calculate the approximate molecular weight of the gas.

Problem Exercise

Name ______________________

Science IIIA Hour ___

Date ______________________

PARTIAL PRESSURES

1. In a gaseous mixture of equal grams of CH_4 and CO, what is the ratio of moles of CH_4 to CO? What is the mole fraction of CH_4?

2. In a gaseous mixture of CH_4 and C_2H_6 there are twice as many moles of CH_4 as C_2H_6. The partial pressure of the CH_4 is 40 millimeters. What is the partial pressure of the C_2H_6?

3. A mixture of 60 grams of nitrogen gas and 60 grams of NH_3 gas is placed in a container under a pressure of 500 millimeters. What is the partial pressure of the nitrogen gas in the mixture?

4. In a gaseous mixture of equal grams of C_2H_6 and CO_2, the partial pressure of the C_2H_6 is 22 millimeters. What is the partial pressure of the CO_2?

5. In a gaseous mixture of CO_2 and CO, the partial pressure of CO_2 is twice the partial pressure of CO. Calculate the ratio of grams of CO_2 to grams of CO.

6. How many grams of pure CO_2 gas would have to be mixed with 34 grams of pure NH_3 gas in order to give a mixture in which the partial pressure of the CO_2 is equal to the partial pressure of the NH_3?

7. In a mixture of .300 moles of oxygen, .2000 moles of SO_2, and .4000 moles of CH_4 at 700 millimeters, what is the partial pressure of the oxygen?

8. In a mixture of 68 grams of NH_3 gas and 88 grams of CO_2 gas under a pressure of 900 millimeters at 50°C, what is the partial pressure of the NH_3?

9. A mixture of 3.0×10^{23} molecules of N_2 and 9.0×10^{23} molecules of CH_4 exerts a total pressure of 730 millimeters. What is the partial pressure of the N_2?

10. The partial pressure of the four gases contained in a 4 liter cylinder at 1015°C were: CH_4 = 52.1 atm., O_2 = 20.9 atm., CO_2 = 83.6 atm., H_2O = 32.4 atm., How many grams of CH_4 gas were there in the cylinder?

MECHANISM OF CHEMICAL REACTIONS

Refinements of Our Atomic Model

Periodicity

Quantitative Description of Reaction Mechanisms in Gases

Quantitative Description of Reaction Mechanisms in Solution

Oxidation - Reduction Reactions

Mechanism of Chemical Reactions

Resource Material

REFINEMENTS OF OUR ATOMIC MODEL

Required Reading:
Atoms, Crystals, Molecules, part 1, Modern Views of Atomic Structure and the Periodic Table, 536 Dr
The Elementary Particles, pages 4-7
Background to the Modern View, The Quantum Numbers and Building the Periodic Table, pages 13-26

Recommended Reading:
Principles of Chemistry, 540 Sa2p (L)
Atomic Structure, pages 33-57

QUESTIONS FOR CONSIDERATION:

1. Neutrons when used as nuclear bullets are unusually penetrating. Why is this true?

2. When energy is absorbed or emitted by atoms it is said to be quantized. Explain.

3. Why is the chemist primarily concerned about the electron distribution outside the atomic nucleus rather than the structure of the nucleus itself?

4. Why are the chemical properties of the elements in the lanthanide series nearly identical? What difficulty does this cause?

5. What is the apparent cause for the variable valence shown by the transition elements such as iron and chromium?

6. What is the Pauli Exclusion Principle?

7. How do the two electrons which occupy the same orbital differ from each other?

Mechanism of Chemical Reactions

REFINEMENTS OF OUR ATOMIC MODEL

I. Review of Basic Structure

A. Fundamental particles

B. Electron structure

C. Electron dot notation

D. Sublevel structure

E. Electron configuration notation

II. Extension of Atomic Structure

A. Atoms of the 4th series

B. Atoms of the 5th series

C. Atoms of the 6th series

III. Quantum Theory

Mechanism of Chemical Reactions

Resource Material

PERIODICITY

Required Reading:	Modern Chemistry, The Periodic Law, pages 68-80
Recommended Reading:	A Short History of Chemistry, 549 As, The Periodic Table, pages 124-145 Crucibles, the Story of Chemistry, Mendeleeff, pages 125-139

QUESTIONS FOR CONSIDERATION:

1. Why is the outer shell electronic structure the basis for placing elements in groups?

2. What is the advantage of classifying the elements?

3. State the Periodic Law as Mendeleyev used it and as it is now stated in modern times.

4. Write the equation which represents the removal of the single outer shell electron from a sodium atom and the equation to represent the addition of an electron to a neutral chlorine atom.

   What particles are produced from the neutral atoms by these reactions?

5. Why is hydrogen frequently placed in two positions on the Periodic Chart?

6. Based on the ideas associated with our present atomic theory, why is it not feasible to find any new elements of low atomic number?

Mechanism of Chemical Reactions

PERIODICITY

I. Early Attempts to Classify Elements

A. Döbereiner

B. Newlands

C. Meyer

II. Mendeleyev's Periodic Table

Mechanism of Chemical Reactions

PERIODICITY

III. The Modern Periodic Table

A. Discovery of the Inert Gases

B. Determination of Atomic Numbers

C. **The Periodic Law**

D. Structure of the Modern Periodic Table

1. Vertical and horizontal divisions

2. Area--from electron addition

Mechanism of Chemical Reactions

PERIODICITY (Cont.)

IV. Periodic Properties

A. Chemical activity

B. Metallic and non-metallic character

C. Atomic diameter

D. Ionization energy

E. Electron affinity

Exercise

Name ____________________

Science IIIA Hour _____

Date ____________________

REFINEMENTS OF OUR ATOMIC MODEL AND PERIODICITY

1. Give the symbols of all elemental ions that have the same electronic configuration as the Ne atom.

2. In each of the following sets of elements or ions circle the correct answer.

a. most metallic	Rb	Na	I	Cl
b. largest atomic diameter	B	Cs	Fe	F
c. most reactive towards heated hydrogen	F	Cl	Br	I
d. most reactive toward cold water	Be	Mg	Ca	Ba
e. most electronegative	O	S	Se	Te
f. lowest ionization energy	Rb	I	Cl	Ca
g. highest electron affinity	Cl	K	Si	Li
h. adding electrons in an f sublevel	Kr	Li	Np	Co
i. contains the most electrons	Ca^{+2}	K	Cl^-	Ar
j. a representative element	Te	Pr	Ti	Kr

3. Why is the radius of an atom not a definitely fixed quantity.

4. Between 1800 and 1860 several attempts were made to classify elements. Name the men involved, the contribution made by each and the approximate date of their work.

5. In the development of the Periodic Table of the Elements Mendeleyev made two important changes which are considered to be unusually brilliant thinking for the period of time in which he lived. What were these two changes?

6. What is the correct explanation for the reversed atomic weights observed by Mendeleyev as, for example, in the case of K and Ar?

7. Name the two contributions or discoveries which completed the work on the periodic chart.

8. Why is Moseley's contribution considered to be so outstanding?

9. Why are there eighteen elements in the fifth period and 32 elements in the sixth period?

10. How many elements are predicted for the eighth period?

11. The original uses for the periodic table are now outdated. What were these uses and what is the presentday use for the periodic table?

12. What is similar about the electron configurations of elements with similar properties?

13. **Why do metals have low ionization energies while nonmetals have high ionization energies?**

14. In the transition elements the electron is being added in a specific level. What is this level and in which periods of the chart are the transition element to be found?

15. How would you expect the ionization energies of two atoms of about equal size but different atomic number to compare? Why is this true?

16. What determines the number of elements in each period of the Periodic Table?

17. What is the probable electron configuration that element 106 would have?

18. How many O-shell orbitals would be filled theoretically in **element 118?**

Mechanism of Chemical Reactions

Resource Material

QUANTITATIVE DESCRIPTION OF REACTION MECHANISMS IN GASES

Required Reading: Modern Chemistry, Chemical Composition, pages 164-167 and pages 169-173; Mass Relations in Chemical Reactions, pages 191-192 and 195-196; Volume Relations in Chemical Reactions, pages 210-216

Recommended Reading: How to Solve General Chemistry Problems, C. H. Sorum Chapter 5, pages 18-35 and Chapter 8, pages 66-81

QUESTIONS FOR CONSIDERATION:

1. What is the distinction between the terms "formula weight" and "molecular weight"?

2. Gasoline tank additives of questionable merit appear on the market from time to time. One such additive, in the form of white tablets, was analyzed by chemists. They found that the substance burned to produce carbon dioxide and water vapor. Each gram of substance, when burned, yielded 3.44 g of CO_2 and .588 g of H_2O. The density of its vapor at STP was found to be 5.715 g per liter. What is the chemical name of the substance? What is the most common use of this substance?

3. A tube contains 1.000 kilograms of hot copper (II)oxide. If 10.00 g of hydrogen are passed through the tube slowly and the water formed is expelled to the air, what remains in the tube and in what quantities?

4. What special property of gases allows a volume-volume problem to be solved by inspection?

5. The average kinetic energy of gas molecules is calculated from the formula $KE = 1/2mv^2$, and is directly proportional to the absolute temperature. If hydrogen gas molecules move at an average speed of 1.2 km/sec at 300 degrees K, what will their average speed, in km/sec, be at 1200 degrees K?

QUANTITATIVE DESCRIPTION OF REACTION MECHANISMS IN GASES

I. Significance of Chemical Formulas

A. Molecular or true formula

B. Empirical or simplest formula

II. Percentage Composition

Problem Exercise

Name ______________________

Science IIIA Hour _____

Date ______________________

PERCENTAGE COMPOSITION

1. Find the formula weight for:

   a. H_2SO_4

   b. N_2H_4

   c. $Ca_3(PO_4)_2$

   d. $C_2H_5O_4$

   e. $CuSO_4 \cdot 5\ H_2O$

2. Find the percentage composition of acetic acid, $HC_2H_3O_2$.

3. Calculate the percentage composition of $NaHCO_3$.

4. What is the percentage composition of $MgSO_4 \cdot 7H_2O$?

5. What is the percentage composition of a soap having the formula $C_{17}H_{35}COONa$?

6. A strip of pure metal weighing 6.356 g is heated in oxygen until it is completely converted to an oxide. The oxide weighs 7.956 g. What is the percentage composition of the metal oxide?

7. Which of these compounds contains the highest percentage of nitrogen:

   a. $Ca(NO_3)_2$

   b. $CaCN_2$

   c. $(NH_4)_2SO_4$

8. Calculate the percentage composition of $Fe_2(SO_4)_3$.

Mechanism of Chemical Reactions, Contd.

QUANTITATIVE DESCRIPTION OF REACTION MECHANISMS IN GASES

III. Determining the empirical formula of a compound

   A. From the percentage composition

      1.

      2.

   B. From the combining weights

   C. Finding the molecular formula

Problem Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

EMPIRICAL FORMULAS

1. A compound of platinum and chlorine is known to consist of 42.1% chlorine. What is its empirical formula?

2. A compound shows the following analysis: potassium 24.6%; manganese 34.8% oxygen 40.5%. What is the empirical formula?

3. Calculate the empirical formula for a compound having 37.7% sodium, 23.0% silicon and 39.3% oxygen.

4. The analysis of a compound shows nitrogen 21.2%; hydrogen 6.1%; sulfur 24.2%; oxygen 48.5%. Find the simplest formula.

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5. A compound has the composition sodium 28.1%; carbon 29.3 %; hydrogen 3.7%; oxygen 39.0%. What is the empirical formula?

6. A compound contains 43.7% phosphorus and 56.3% oxygen. What is the empirical formula?

7. 5.46 grams of carbon combines with oxygen to form 20.0 grams of the oxide. Find the empirical formula.

8. The analysis of a gas reveals this composition: carbon 92.3%; hydrogen 7.7%. Its molecular weight is 26 amu. What is the molecular formula?

Problem Exercise

Name ______________________
Science IIIA Hour ________
Date Due __________________

EMPIRICAL AND MOLECULAR FORMULAS

1. A sample of an oxide of iron contains 27.59% oxygen and 72.4% iron. Calculate the empirical formula.

2. 2.975 grams of tin are dissolved in excess hydrochloric acid, and the result evaporated to dryness. The residue weighs 4.725 grams. Calculate the empirical formula for this compound produced in the reaction. Write the balanced chemical equation for the reaction.

3. 13.78 grams of phosphorus are heated with sulfur in the correct proportion. The weight of the solid product is 24.45 grams. Find the empirical formula for this compound. Write the balanced chemical equation for the reaction.

4. 103.5 grams of lead are heated in air and converted to lead oxide. The final amount of the product is 114.17 grams. Calculate the empirical formula. Write a balanced chemical equation for this reaction.

5. 9.23 grams of calcium are heated in an excess of nitrogen. The final product weighs 11.38 grams. Calculate the empirical formula for the compound produced and write the equation for the reaction.

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6. It was found that 10.0 g of a pure compound contains 3.65 g of K, 3.33 g of Cl, and 3.02 g of O. Calculate the empirical formula of the compound.

7. In the laboratory 2.38 g of copper combined with 1.19 g of sulfur. In a duplicate experiment 3.58 g of copper combined with 1.80 g of sulfur. Are these results in agreement with the Law of Definite Proportions?

8. A compound contains 20% hydrogen and 80% carbon. The molecular weight of the compound is known to be 30 a.m.u. Calculate the empirical formula and the molecular formula for the compound.

9. A compound contains 40.00% of carbon, 6.67% hydrogen, and 53.33% oxygen. The molecular weight of the compound is 180 a.m.u. Find the empirical formula and the molecular formula for the compound.

10. The composition of urea is 20.00% carbon, 26.67% oxygen, 46.67% nitrogen, and 6.67% hydrogen. The molecular weight of urea is 60 a.m.u. Calculate the empirical formula and the molecular formula for the compound.

Laboratory Problem

THE EMPIRICAL FORMULA OF A COMPOUND

PROBLEM:

To determine the empirical formula of copper sulfide.

PROCEDURE:

A clean crucible is to be dried by heating strongly at the highest temperature of the burner for five minutes. Cool and weigh. The weight of the powdered copper should be about .9 gram. The copper is to be weighed directly in the crucible.

The copper is then covered with excess powdered sulfur, at least one gram. The crucible is covered and heated gently by holding the burner in the hand and moving the flame around the crucible. Avoid boiling the sulfur out of the crucible before it has reacted with the copper. Continue this careful heating until blue flames of burning sulfur are no longer visible along the edge of the cover. Now place the burner under the crucible and heat at maximum heat for 1-2 minutes. The bottom third of the crucible should be red hot. Cool and weigh. The crucible cover need not be weighed but must remain on during all heating and cooling operations.

DATA:

SUMMARY QUESTIONS:

1. Calculate the empirical formula for copper sulfide from the experimental data.
2. Discuss the sources of error in this experiment. For each error listed indicate the effect which this error would have on the experimental result.
3. Write balanced equations for the reactions of copper and sulfur and for excess sulfur burning in air.

Problem Exercise 1

Name ______________________________

Science IIIA Hour ______

Date ______________________________

WEIGHT - WEIGHT PROBLEMS

1. How many grams of oxygen can be obtained by heating 150 g of HgO?

2. How many grams of potassium chlorate must be heated to give 60 g of oxygen?

3. How many grams of $KClO_3$ will be required to liberate 20 g of oxygen?

4. How many moles of oxygen can be prepared from 150 moles of $KClO_3$?

5. How many moles of oxygen will be required to burn 85 g of Mg?

6. How many moles of $KClO_3$ will be required for the preparation of 144 g of oxygen?

7. How many grams of oxygen will be required to prepare 150 g of P_4O_{10}?

8. How many pounds of KCl will be formed if 60 lb of $KClO_3$ are decomposed by heating?

9. How many tons of sulfur must be burned to produce 16 tons of SO_2 gas?

10. How many moles of hydrogen will be liberated by the action of 50 g of pure Mg on an excess of hydrochloric acid?

11. How many grams of hydrogen will be liberated by the reaction of an excess of sulfuric acid on 3.2 g atoms of Zn?

12. How many grams of pure zinc must be treated with an excess of dilute sulfuric acid in order to liberate 10 g of hydrogen?

Problem Exercise 2

Name ____________________________

Science IIIA Hour ____

Date ____________________________

WEIGHT-WEIGHT PROBLEMS

1. How many moles of hydrogen will be liberated when 1.4 g atoms of zinc react with a solution containing 1.1 moles of HCl?

2. How many gram atoms of zinc would be required to liberate all the hydrogen from a solution of hydrochloric acid which contains 73 g of HCl?

3. How many grams of CuO can be reduced by 6.4 g of hydrogen?

4. How many pounds of ZnO will be formed by the complete oxidation of 80 pounds of pure zinc?

5. How many tons of CO_2 gas will be formed when 10 tons of pure C are burned in air?

6. How many grams of copper oxide (CuO) can be formed by the oxygen liberated when 150 g of silver oxide are decomposed?

7. How many grams of aluminum must be treated with excess H_2SO_4 in order to generate enough hydrogen gas to reduce 200 g of copper oxide (CuO)?

8. A sample of pure MgO was first dissolved in hydrochloric acid to give a solution of $MgCl_2$ and was then converted to a precipitate of pure, dry $Mg_2P_2O_7$ weighing 12.00 g. Calculate the weight of the sample of MgO.

9. A sample of impure copper weighing 2.50 g was dissolved in nitric acid to yield $Cu(NO_3)_2$. It was subsequently converted, first to $Cu(OH)_2$, then to CuO, then to $CuCl_2$, and finally to $Cu_3(PO_4)_2$. There was no loss of copper in any step. The pure dry $Cu_3(PO_4)_2$ that was recovered weighed 2.00 g. Calculate the percent of pure copper in the impure sample.

10. A 1.000 g sample of crude sulfide ore in which all sulfur was present as ZnS was analyzed as follows: The sample was digested with hot concentrated HNO_3 until all sulfur was converted to sulfuric acid. The sulfate was then completely precipitated as $BaSO_4$. The insoluble $BaSO_4$ was filtered off, washed, dried, and weighed. This yielded 1.167 g of $BaSO_4$. Calculate the per cent of ZnS in the crude ore.

Problem Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

WEIGHT - VOLUME PROBLEMS

1. How many liters of oxygen gas, measured at STP can be prepared by heating .514 mole of MgO?

2. How many liters of oxygen gas, measured at STP will be required for the preparation of 200 grams of P_4O_{10}?

3. How many gram atoms of sulfur can be oxidized to SO_2 by 50 liters of oxygen gas measured at STP? How many liters of SO_2 gas, measured at STP will be produced?

4. How many liters of dry H_2 gas, measured at STP will be evolved by the action of an excess of HCl on 80 g. of aluminum?

5. How many liters of dry H_2 gas, measured at 20°C and 740 mm., will be evolved by the action of excess dilute H_2SO_4 on 100 g. of pure zinc?

6. How many grams of tin would be formed if an excess of pure SnO_2 were reduced with 1500 cc. of dry hydrogen gas measured at 300°C and 740 mm.?

7. How many liters of CO_2 gas, measured at 200°C and 1.2 atm. pressure, will be formed when 40 g. of carbon are burned?

8. If 2.4 moles of C_3H_8 are burned in a plentiful supply of oxygen, how many grams of H_2O and how many liters of CO_2, measured at STP, will be formed?

9. If 2.0 g. of crude sulfur gave, on complete combustion, 996 cc. of SO_2 measured at standard conditions, calculate the percent of sulfur in the crude material.

10. When 100 g. of aluminum were treated with HCl until all of the metal was dissolved, the hydrogen gas evolved was collected over water at a temperature of 22°C and a barometric pressure of 742 mm. What volume in liters did it occupy?

Problem Exercise

Name ________________________

Science IIIA Hour ________

Date Due ____________________

VOLUME - VOLUME PROBLEMS

1. Carbon monoxide burns in oxygen to form carbon dioxide. What volume of carbon dioxide is produced when 15 liters of carbon monoxide burn? What volume of oxygen is required? All volumes are measured at STP.

2. Acetylene gas, C_2H_2, burns in oxygen to form carbon dioxide and water vapor. How many liters of oxygen are needed to burn 25 liters of acetylene? How many liters of carbon dioxide are formed? All volumes are measured at STP.

3. Ethane gas, C_2H_6, burns in air to produce carbon dioxide and water vapor. How many liters of carbon dioxide are formed when 12 liters of ethane are burned? All gases are measured at standard conditions.

4. How many liters of air are required to furnish the oxygen to complete the reaction in Problem 3? Assume the air to be 21% oxygen.

5. What volumes of hydrogen and nitrogen are required to produce 20 liters of ammonia gas? All gases are measured at standard conditions.

6. How many liters of ammonia can be prepared from 10 liters of nitrogen and 25 liters of hydrogen?

7. How many liters of oxygen gas will be required to burn 160 liters of hydrogen gas? The volumes of both gases are measured at standard conditions.

8. Ammonia gas is oxidized by oxygen gas in the presence of a catalyst as follows: $4NH_3 + 5O_2 \rightarrow 6H_2O + 4NO$. How many liters of oxygen will be necessary to oxidize 500 liters of NH_3 gas? How many liters of NO and how many liters of steam will be formed. All gases are measured under the same conditions of temperature and pressure.

9. How many liters of oxygen gas will be required for the complete combustion of 200 liters of C_2H_6 gas? How many liters of CO_2 and how many liters of steam will be formed? All gases are measured at the same temperature and pressure.

10. How many liters of oxygen gas will be required to burn 100 liters of H_2S gas to H_2O and SO_2? How many liters of SO_2 will be formed? All gases are measured at the same temperature and pressure.

11. How many cubic feet of oxygen gas will be required for the oxidation of 4000 cu. ft. of SO_2 gas? How many cubic feet of SO_3 gas will be formed? All gases are measured under the same conditions of temperature and pressure.

12. How many cubic feet of dry nitrogen gas, measured at 22°C and 740 mm. will be required to combine with 1200 cu. ft. of dry hydrogen gas, measured at 30°C and 800 mm.? How many cubic feet of ammonia gas, measured at 100°C and 750 mm., will be formed?

Review Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

EQUATIONS, WEIGHT-WEIGHT, WEIGHT-VOLUME, VOLUME-VOLUME PROBLEMS

1. Write balanced equations for the following reactions:
   a. the heating of silver oxide
   b. the oxidation of chromium
   c. the burning of butane, C_4H_{10}, in air
   d. the electrolysis of water
   e. the heating of magnesium chlorate
   f. the heating of ferric hydroxide
   g. the reaction of nickel with hydrochloric acid
   h. the reaction of potassium oxide with water
   i. the reaction of nitrogen trioxide, N_2O_3, with water
   j. the heating of aluminum carbonate
   k. the reaction of lithium on water
   l. the reaction of magnesium sulfite and nitric acid
   m. the reaction of barium hydroxide and sulfuric acid
2. How many grams of sodium oxide will be formed when 20 grams of sodium burn in air?
3. 2 grams of calcium metal are placed on 20 grams of water. How many grams of hydrogen are formed?

4. The hydrogen generated by the action of 15 grams of chromium on excess sulfuric acid is reacted with iodine. What weight of iodine is required?

5. What volume of CO_2 is formed when 30 liters of propane C_3H_8 burned in air? All volumes are measured at the same conditions of temperature and pressure?

6. A 5.00 gram sample of a crude sulfide ore in which all the sulfur was present as As_2S_5 was analyzed as follows: The sample was digested with concentrated HNO_3 until all sulfur was converted to sulfuric acid. The sulfate was then completely precipitated as $BaSO_4$, and yielded .752 g of $BaSO_4$. Calculate the per cent of As_2S_5 in the crude ore.

7. How many liters of oxygen gas, measured at STP, will be evolved by the heating of 50 grams of mercuric oxide?

8. 2 liters of dry hydrogen gas measured at 20°C and 740 mm are evolved when zinc reacts with nitric acid. How many grams of zinc are needed?

Problem Exercise

Name ____________________
Science IIIA Hour ____
Date ____________________

GRAHAM'S LAW OF DIFFUSION

1. A gas A is nine times as dense as a gas B. In a given diffusion apparatus and at a certain temperature and pressure, gas B diffuses 15 centimeters in 10 seconds. In the same apparatus and at the same temperature and pressure how fast will gas A diffuse?

2. The density of CH_4 is 16.0 gram per 22.4 liters. The density of HBr is 81.0 gram per 22.4 liters. If CH_4 diffuses 2.30 feet in one minute in a certain diffusion apparatus, how fast will HBr diffuse in the same apparatus at the same temperature and pressure?

3. A gas A is 16 times as dense as gas B. How do their rates of diffusion differ?

4. Gas A diffuses 3.20 times as fast as gas B. How do their densities compare?

5. How do the rates of diffusion of HBr and SO_2 compare?

6. In a given piece of apparatus it was found that 2.0 cubic centimeters of CH_4 gas diffused in one second while 1.4 cubic centimeters of oxygen diffused in one second. On the basis of these facts, what should the formula for a molecule of oxygen gas be?

7. In a given diffusion apparatus 15.0 cubic centimeters of HBr gas were found to diffuse in one minute. How many cubic centimeters of CH_4 gas would diffuse in one minute in the same apparatus at the same temperature?

8. An unknown gas diffuses at a rate of 8 cubic centimeters per second in a piece of apparatus in which CH_4 gas diffuses at the rate of 12 cubic centimeters per second. Calculate the approximate molecular weight of the gas.

Mechanisms of Chemical Reaction

Resource Material

QUANTITATIVE DESCRIPTION OF REACTION MECHANISM IN SOLUTIONS

Required Reading:	Modern Chemistry, pages 267-68, 270-72, 306-10
Recommended Reading:	How to Solve General Chemistry Problems, C. H. Sorum, Chapters 12, 13, 14, 15, and 19, pages 105-26 and 180-89.

QUESTIONS FOR CONSIDERATION:

1. What advantage is there in expressing concentration in terms of molarity or normality? What is the disadvantage?

2. In what cases of expressing concentration is molality preferred over molarity?

3. Why do solutes depress the freezing points of solvents and elevate the boiling points?

4. What advantage does the use of the equivalent as the reacting quantity have over the mole?

5. A newly discovered compound X is composed of carbon, hydrogen, and oxygen and has the empirical formula CH_4O. The compound is solid at room temperature and decomposes into other products when an attempt is made to convert it to a gaseous compound. The compound is insoluble in water. What possible method can the chemist use to get the true formula?

QUANTITATIVE DESCRIPTION OF REACTION MECHANISMS IN SOLUTIONS

I. Per cent Strength -

II. Densities of Solution -

III. Molarity -

IV. Molality -

V. Raoult's Law -

Problem Exercise

Name ____________________

Science IIIA Hour ____

Date ____________________

PER CENT STRENGTH AND DENSITIES OF SOLUTION

1. Fifteen grams of potassium chloride are dissolved in 75 grams of water. Calculate the per cent strength of the solution.

2. How many grams of sodium chloride are there in 80 grams of 25% solution of sodium chloride in water?

3. How many grams of sugar would have to be dissolved in 50 grams of water to give a 15 per cent solution?

4. Twenty grams of a compound were dissolved in 70 grams of water. Calculate the per cent strength of the resulting solution.

5. Fifty-two grams of a 19 per cent solution of magnesium nitrate were evaporated to dryness. How many grams of dry magnesium nitrate were obtained?

6. How many grams of water and how many grams of salt would you have to mix to get 65 grams of a 6 per cent solution?

7. How many grams of calcium chloride would have to be dissolved in 30 grams of water to give a 20 per cent solution?

8. Ten grams of NH_4Cl are dissolved in 100 grams of a 10 per cent solution of NH_4Cl in water. Calculate the per cent strength of the resulting solution.

9. Eighty grams of an 8 per cent solution of salt in water were mixed with 30 grams of a 6 per cent solution of salt in water. What was the per cent strength of the resulting solution?

10. A 14 per cent solution of Na_2CO_3 in water has a density of 1.15 gram per cubic centimeter. If 85.0 cubic centimeters of this solution were evaporated to dryness, how many grams of dry Na_2CO_3 would be obtained?

11. A 14 per cent solution of Na_2CO_3 in water has a density of 1.15 gram per cubic centimeter. How many cubic centimeters of this solution must be evaporated to obtain 15 grams of dry Na_2CO_3?

12. Twenty cubic centimeters of a 15 per cent solution of salt in water, when evaporated to dryness, gave 3.6 grams of dry salt. Calculate the density of the 15 per cent solution.

13. Measured at standard conditions, 19.6 liters of dry HCl gas were dissolved in 48.0 grams of H_2O. The resulting solution had a density of 1.20 grams per cc. Calculate the per cent strength of the solution and the volume which it occupied.

14. Twenty grams of NH_3 were dissolved in enough water to give 100 cubic centimeters of solution of density 0.920. Calculate the per cent strength of the solution.

15. A 44 per cent solution of H_2SO_4 has a density of 1.343 grams per cc. Twenty-five cubic centimeters of 44 per cent sulfuric acid solution were treated with an excess of zinc. What volume did the dry hydrogen gas which was liberated occupy at standard conditions?

Problem Exercise

Name ______________________

Science IIIA Hour _____

Date ______________________

MOLARITY

1. How many grams of K_2SO_4 will be required to prepare 1.00 liter of 0.500M K_2SO_4?

2. How many grams of $Al_2(SO_4)_3$ will be required to prepare 300 ml of 0.200 M $Al_2(SO_4)_3$?

3. If 12 g of NaOH were dissolved in enough water to give 500 ml of solution, calculate the molarity of the solution.

4. How many grams of KOH will be required to prepare 400 ml of 0.12M KOH?

5. How many liters of 0.20M Na_2CO_3 can be prepared from 140 g of Na_2CO_3?

6. A solution NaCl contained 12 g of NaCl in 750 ml of solution. What was the molarity of the solution?

7. If 200 ml of .3M Na_2SO_4 are evaporated to dryness, how many grams of dry Na_2SO_4 will be obtained?

8. 10 cc. of a 70% solution of sulfuric acid of density of 1.61 g/cc were dissolved in enough water to give 25 cc. of solution. What was the molarity of the original 70% solution? What was the molarity of the final solution?

9. In 3.58M H_2SO_4 there is 29% H_2SO_4. Calculate the density of 3.58M H_2SO_4.

10. If 18 liters of dry HCl gas measured at 20°C and 750 mm are dissolved in enough water to give 400 ml of solution, calculate the molarity of the solution.

Problem Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

MOLALITY AND RAOULT'S LAW

1. Calculate the density of an aqueous solution of K_2CO_3 which is 3.10 molal and 2.82 molar.

2. Calculate the molality of a 28% $HClO_4$ solution.

3. A 4.1 molar solution of NaCl in water has a density of 1.2 grams per cc. Calculate the molality of 4.1M NaCl.

4. A quantity of 60 g of a nonelectrolyte dissolved in 1000 g of H_2O lowered the freezing point 1.02°C. Calculate the approximate molecular weight of the nonelectrolyte.

5. When 4.2 g of a nonelectrolyte were dissolved in 40 g of water, a solution which froze at -1.52°C was obtained. Calculate the approximate molecular weight of the nonelectrolyte.

6. If 20 g of $C_6H_{10}O_5$, a nonelectrolyte, were dissolved in 250 g of water, calculate the boiling point of the solution at 760 mm.

7. When 6 grams of a nonelectrolyte were dissolved in 54 grams of water, a solution was obtained which boiled at 100.41° C at 760 mm. Calculate the approximate molecular weight of the nonelectrolyte.

8. Six grams of C_2H_5OH, a nonelectrolyte, were dissolved in 300 grams of water. Calculate the freezing point of the solution.

9. When 12 grams of a nonelectrolyte were dissolved in 300 grams of water, a solution which froze at -1.62°C was obtained. What was the approximate molecular weight of the nonelectrolyte?

10. When 5.12 grams of the non-ionizing solute, naphthalene ($C_{10}H_8$), are dissolved in 100 grams of CCl_4 (carbon tetrachloride), the boiling point of the CCl_4 is raised 2 degrees. What is the boiling point constant for carbon tetrachloride?

QUANTITATIVE DESCRIPTION OF REACTION MECHANISMS IN SOLUTION

I. Determination of molecular weights and true formulas

  A. Vapor Density -

  B. Graham's Law -

  C. Raoult's Law -

II. Equivalent weight

  A. Element -

  B. Compound -

III. Normality

Problem Exercise

Name ______________________________

Science IIIA Hour ______

Date ______________________________

FINDING A TRUE OR MOLECULAR FORMULA

1. When dissolved in 1000 g. of water, 20.0 g. of a nonelectrolyte gave a solution which froze at 0.80 deg. C. The compound contained 52.17% C, 34.78% O, and 13.05% H. Find the molecular formula.

2. Measured at standard conditions, 100 cc. of a gas weighed 0.1232 g. The compound contained 85.71% C and 14.29% H. Find the molecular formula.

3. An unknown gas was found to diffuse 2.2 ft. in the same time that methane gas (CH_4) diffused 3.0 ft. The unknown gas was found to contain 80% C and 20% H. Find the molecular formula.

4. A compound was found, on analysis, to consist of 50.00% O, 37.50% C, and 12.50 H. When dissolved in 100.0 cc. of water, 1.666 g. of the compound gave a nonconducting solution which froze at -1.00 deg. C. Find the molecular formula.

5. When converted to a vapor, 0.347 g. of a liquid compound occupied a volume of 100 cc. at 0 deg. C. and 760 mm. The compound was found to consist of 92.30% C, and 7.70% H. Find the molecular formula.

6. In a given diffusion apparatus 15.0 cc. of HBr gas diffused in 1 min. In the same apparatus and under the same conditions 33.7 cc. of an unknown gas diffused in 1 min. The unknown gas contained 75% C and 25% H. Find the molecular formula.

7. A compound was found on analysis to consist of 52.17% C, 34.78% O, and 13.05% H. It was found that 2.47 g. of the compound dissolved in 100 g. of water gave a nonconducting solution which froze at -1.00 deg. C. Find the molecular formula.

8. Measured at 0 deg. C. and 760 mm., 20 cc. of a gaseous compound weighed 0.0232 g. The compound contained 92.30% C and 7.70% H. Find the molecular formula.

Problem Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

EQUIVALENT WEIGHT

1. When 0.300 g of a metal was treated with HCl, 0.0177 g. of hydrogen was liberated. Calculate its equivalent weight.

2. When 0.030 g. of a metal will combine with 0.02 g. of oxygen, what is the equivalent weight of the metal?

3. The oxide of a metal contains 43.66% of the metal. Calculate the equivalent weight of the metal.

4. How many equivalents are there in 50 g. of each of the following:
   a. H_2SO_4 =
   b. HNO_3 =
   c. Na_2CO_3 =
   d. KOH =
   e. K_3PO_4 =
   f. $Al_2(SO_4)_3$ =

5. How many grams of NaOH will be required to react with 0.2 equivalent of HCl?

6. How many equivalents of NaCl will be required to react with 100 g. of $AgNO_3$?

7. How many cubic centimeters of a 24 percent solution of HCl, whose density of 1.12 gram per cubic centimeter, will be required to neutralize a solution containing 0.800 equivalent of KOH?

8. How many grams of chromate ion, CrO_4^{-2}, will be required to precipitate 0.640 equivalent of silver ions from solution?

9. A solution containing 12 grams of NaOH was added to a solution containing 0.4000 equivalent of Fe^{+3}. How many grams of $Fe(OH)_3$ were precipitated?

10. How many equivalents of barium ion will be required to precipitate 11.68 grams of $BaSO_4$ from a solution of Na_2SO_4? What will be the weight in grams of these Ba^{+2} ions?

11. How many grams of silver ions will be required to react with 0.200 equivalent of PO_4^{-3}? How many grams of Ag_3PO_4 will be formed?

12. How many liters of dry HCl gas, measured at 20°C and 740 mm., will be formed by the action of concentrated sulfuric acid on 0.50 equivalent of $CaCl_2$?

Problem Exercise

Name ______________________

Science IIIA Hour __

Date ______________________

EQUIVALENT WEIGHT

1. How many grams of Na_2CO_3 will react with a solution containing 0.300 equivalent of HCl?

2. How many liters of dry HCl gas, measured at STP, will be formed by the action of concentrated sulfuric acid on 0.400 equivalent NaCl?

3. How many grams of carbonate ion, CO_3^{-2}, will be required to precipitate 0.500 equivalent of aluminum ions from solution?

4. Chromic sulfate reacts with barium nitrate in an exchange reaction. How many grams of barium nitrate are required to react with 6.53 grams of chromic sulfate?

5. A solution of 42 grams of AlF_3 was added to a solution containing 0.6 equivalent of KOH. How many grams of $Al(OH)_3$ were formed?

6. How many cubic centimeters of a 30 percent solution of sulfuric acid whose density is 1.3 gram per cubic centimeter will be required to neutralize a solution containing 0.400 equivalent of NaOH?

Problem Exercise

Name ______________________________

Science IIIA Hour ______

Date ______________________________

NORMALITY

1. How many grams of KOH will be required for the preparation of 500 ml. of .4N KOH?

2. How many milliliters of .3N HNO_3 will be required to react with 24 ml. of .25N KOH?

3. What is the normality of a solution which contains 8 g. of NaOH per 400 ml. of solution?

4. A sample of 50 ml. of hydrochloric acid was required to react with .4 g of NaOH. Calculate the normality of the hydrochloric acid.

5. How many grams of KOH will be required to react with 100 ml. of .8N HCl?

6. How many milliliters of .25N HCl will be required to neutralize 100 ml. of the solution containing 8.00 g. of NaOH?

7. How many milliliters of 0.500 N KOH will be required to precipitate the ferric ions from 60.0 milliliters of 1.00 M $FeCl_3$?

8. It required 100 cubic centimeters of a 12 percent solution of KOH of density 1.15 gram per cubic centimeter to neutralize 800 milliliters of sulfuric acid. Calculate the normality of the acid.

9. Calculate the percent of HCl in a 12.0 N HCl, whose density is 1.20 gram per cubic centimeter.

10. Calculate the density of 7.36 N HCl which contains 24 percent HCl.

11. a. What is the molarity of 0.015 N H_3PO_4?

    b. What is the molarity of 0.12 N H_2SO_4?

    c. What is the molarity of 0.25 N HCl?

    d. What is the normality of 0.02 M H_2SO_4?

    e. What is the normality of 0.15 M $Al_2(SO_4)_3$?

LABORATORY PROBLEM

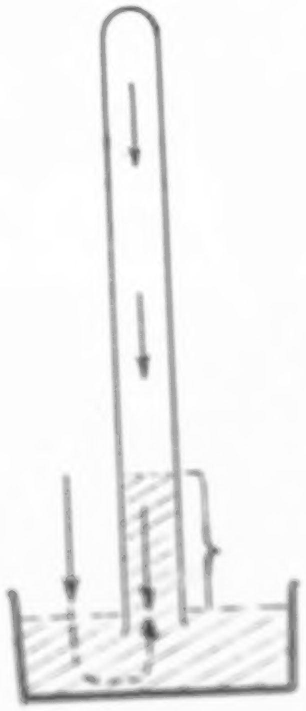
EQUIVALENT WEIGHT OF MAGNESIUM

PROBLEM: To determine the equivalent weight of magnesium.

DIRECTIONS: Determine the weight of a piece of bright magnesium ribbon 4.0-5.5 cm. long. The weight of the metal must be accurately known to the third decimal place and is not to exceed 0.045 g. Roll the ribbon into a coil and tie it securely with a 40 cm. piece of thread.

Pour 5 ml. of concentrated HCl into a gas measuring tube. Tilting the tube at a 45° angle, carefully pour water from the pneumatic trough into the tube. Do not mix the acid and water. Lower the coil into the water to a depth of 5 cm. Invert the measuring tube in the trough and clamp it so that it rests on the bottom.

DATA:



SUMMARY QUESTIONS:

1. Write the equation for the reaction.

2. Calculate the percent error.

3. Discuss the sources of error in this experiment. For each source of error mentioned, indicate the effect which this source has on the value for the experimental equivalent weight.

TITRATION TECHNIQUES

THEORY OF TITRATION:

The process of TITRATION is an application of the basic concept of chemical equivalents; "things equivalent to the same thing are equivalent to each other."

By TITRATION it is possible to determine the number of equivalents of solute in any basic or acid solution.

$$\#\text{equivalents acid} = \#\text{equivalents base}$$

A solution containing equivalent amounts of acid and base will be chemically neutral. This condition can be observed visually by use of various indicators, or more precisely determined by measurement with electrical instruments.

$$\text{Since} \quad N = \frac{\#\text{eq.}}{\#\text{liters}} \quad ; \quad \#\ \text{Eq} = N \cdot \#\ \text{liters}$$

For a neutral solution the $\boxed{N_{acid} \cdot V_{acid} = N_{base} \cdot V_{base}}$

To measure the N of an acid solution it is necessary to titrate with a base of known normality. (The known is called the Reference Standard). The process of titration is simply the process of measuring the volume of "standard" solution required to neutralize a given volume of a solution of unknown normality.

TECHNIQUES OF TITRATION:

A. Use of the titrating buret

1. mounting

2. operational techniques

3. use of scales

B. Operational Procedures

1. selection of indicator

2. homogeneous mixtures

3. volume ratio of standard to known

4. initial titration

5. final titration

C. Care of Burets

1. cleaning

2. storage

D. Use of dropping pipets

Laboratory Problem

TITRATION OF AN ACID AND A BASE

PROBLEM:

To determine the normality and percent strength of hydrochloric acid of unknown concentration. (Density of HCl is 1.2 g/cc.)

PROCEDURE:

Run one milliliter of the HCl acid into a 50 milliliter flask taking the initial and final reading of the burette very carefully. Add one or two drops of phenolphthalein and titrate with the standard 0.4 N base. Repeat the procedure on two additional samples of HCl.

DATA:

Mechanism of Chemical Reactions

Resource Material

OXIDATION - REDUCTION REACTIONS

Required Reading: *Modern Chemistry*, pages 127-128 and pages 336-343.

Recommended Reading: *Fundamentals of General Chemistry*, pages 103-107 (5.6, 5.7) and pages 107-111 (5.9 - 5.13).

QUESTIONS FOR CONSIDERATION:

1. What is the distinquishing feature of any chemical reaction which experiences oxidation?

2. Indicate which of the following are oxidation - reduction reactions:

$2Na + Cl_2 \rightarrow 2NaCl$

$C + O_2 \rightarrow CO_2$

$2H_2O \rightleftarrows 2H_2\uparrow + O_2\uparrow$

$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

$NH_3 + HCl \rightarrow NH_4^+ + Cl^-$

$2KClO_3 + \Delta \rightarrow 2KCl + 3O_2\uparrow$

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

3. Discuss the relationship between the valence of a chemical element and its oxidation number.

4. Discuss the oxidation numbers for the following:
   a. a free element, atom or molecule
   b. monatomic ions
   c. combinations involving two nonmetals, two metals
   d. oxidation number of hydrogen
   e. oxidation number of oxygen
   f. the oxidation number of a compound

5. Determine the oxidation number for each element in the following:

   a. Fe_{III}
   b. $KMnO_4$
   c. $Al_2(Cr_2O_7)_3$
   d. OF_2
   e. CH_4
   f. Mn_2O_7
   g. SCl_2
   h. sulfur and tin_{IV}
   i. sulfur and $arsenic_{III}$
   j. $K_4(Fe(CN)_6)$

6. Explain how the coefficients for the reactants are determined when balancing a redox equation.

7. Balance the following redox equations:

   a. $NaH + O_2 \rightarrow Na_2O + H_2O$
   b. $C_4H_{10}O + O_2 \rightarrow CO_2 + H_2O$

OXIDATION - REDUCTION REACTIONS

(Molecular Equations)

I. Characteristics of Oxidation - Reduction Reactions
    A. Oxidation
    B. Reduction

II. Valence and Oxidation Numbers
    A. Difference between valence and oxidation number
        1. valence

        2. oxidation number

    B. Determination of oxidation number
        1. free elements
        2. monatomic ions
        3. binary compounds
            a. metal nonmetal
            b. two nonmetals
        4. oxygen and hydrogen
        5. ternary compounds

III. Steps in Balancing Molecular Redox Equations
    A.

    B.

    C.

    D.

Mechanism of Chemical Reaction

#1

Name ______________________________

Science IIIA Hour _____

Date ______________________________

OXIDATION-REDUCTION REACTIONS

(Molecular Form)

1. $FeCl_3 + H_2S = FeCl_2 + HCl + S$

2. $HClO + As_2O_3 = As_2O_5 + HCl$

3. $C + H_2SO_4 = CO_2 + SO_2 + H_2O$

4. $I_2 + P_4O_6 + H_2O = HI + P_4O_{10}$

5. $Na_2SnO_2 + Na_2O_2 + H_2O = Na_2SnO_3 + NaOH$

6. $HNO_3 + P + H_2O = H_3PO_4 + NO$

7. $MnO_2 + HCl = MnCl_2 + Cl_2 + H_2O$

8. $Sb_2S_3 + HNO_3 = NO + S + Sb_2O_5 + H_2O$

Mechanism of Chemical Reaction
#2

Name ____________________
Science IIIA Hour______
Date ____________________

OXIDATION-REDUCTION REACTIONS
(Molecular Form)

1. $KClO_3 + 6HCl = KCl + Cl_2 + H_2O$

2. $Na_3CrO_3 + H_2O_2 = Na_2CrO_4 + NaOH + H_2O$

3. $KMnO_4 + K_2SO_3 + H_2O = MnO_2 + K_2SO_4 + KOH$

4. $Bi(OH)_3 + Na_2SnO_2 = Bi + Na_2SnO_3 + H_2O$

5. $HCl + KMnO_4 = KCl + MnCl_2 + Cl_2 + H_2O$

6. $FeSO_4$ + $KMnO_4$ + H_2SO_4 = $Fe_2(SO_4)_3$ + $MnSO_4$ + K_2SO_4 + H_2O

7. $KMnO_4$ + H_2SO_4 + $NaCl$ = $KHSO_4 \uparrow$ $NaHSO_4$ + $MnSO_4$ + Cl_2 + H_2O

8. $KClO_3$ = KCl + $KClO_4$

9. As_2S_3 + HNO_3 + H_2O = H_3AsO_4 + H_2SO_4 + NO

10. $Al(C_2H_5)_3$ + O_2 = Al_2O_3 + CO_2 + H_2O

OXIDATION - REDUCTION REACTIONS

(Ionic Form)

I. Methods of Representing Chemical Reactions

A. Molecular Equation

B. Ionic Equation

C. Net Ionic Equation

II. Balancing Net Ionic Redox Reactions

A. Equality of Charges

B. The use of H^+ and OH^- ions in balancing ionic redox equations

Name ____________________
Science IIIA Hour ____
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OXIDATION - REDUCTION

(Ionic Form)

1. $BiO_3^{-2} + Mn^{+2} = MnO_4^{-1} + Bi^{+3}$

2. $As_2S_3 + NO_3^{-1} = NO + H_3AsO_4 + SO_4^{-2}$

3. $NO_3^{-1} + Cl^{-1} = NO + Cl_2$

4. $NO_3^{-1} + H_2S = NO + S$

5. $CdS + NO_3^{-1} = Cd^{+2} + NO + S$

6. $Cr_2O_7^{-2} + SO_3^{-2} = Cr^{+3} + SO_4^{-2}$

7. $MnO_4^{-1} + Sn(OH)_4^{-2} = MnO_2 + Sn(OH)_6^{-2}$

8. $Cr(OH)_4^{-1} + Na_2O_2 + OH^{-1} = CrO_4^{-2} + Na^{+1} + OH^{-1}$

9. $SO_3^{-2} + H_2O_2 = SO_4^{-2} + H_2O$

10. $SnS + NO_3^{-1} = SnO_2 + SO_4^{-2} + NO_2$

EQUIVALENT WEIGHT AND STRENGTH OF SOLUTIONS IN REDOX REACTIONS

I. Equivalent Weight

II. Strength of Solutions

A. Normal

B. Molar

Name ____________________________

Science IIIA Hour ______

Date ____________________________

OXIDATION - REDUCTION REACTIONS

1. How many grams are there in one gram-equivalent weight of sulfuric acid as used in the following reaction?

$$H_2SO_4 \quad + \quad HI \quad = \quad H_2S \quad + \quad I_2$$

2. How many grams of $KClO_3$ will be required to react with 2.00 equivalent of HCl in the following reaction?

$$KClO_3 \quad + \quad HCl \quad = \quad KCl \quad + \quad H_2O \quad + \quad Cl_2$$

3. How many equivalents of $KMnO_4$ will be required to react with 30 grams of $FeSO_4$ in the following reaction?

$$Fe^{+2} \quad + \quad MnO_4^{-1} \quad = \quad Fe^{+3} \quad + \quad Mn^{+2}$$

4. How many grams of Na_2SnO_2 will be required to react with and reduce 0.2000 equivalent of $KClO_3$ in the following reaction?

$$ClO_3^{-1} \quad + \quad SnO_2^{-2} \quad = \quad Cl^{-1} \quad + \quad SnO_3^{-2}$$

5. How many equivalents of NaClO will be required to oxidize 50 grams of H_2SO_3 in the following reaction?

$$ClO^{-1} + H_2SO_3 = Cl^{-1} + SO_4^{-2}$$

6. How many grams of MnO_4^{-1} ions will be required to oxidize 1.20 equivalents of Fe^{+2} ions in the following reaction?

$$MnO_4^{-1} + Fe^{+2} = Mn^{+2} + Fe^{+3}$$

7. How many equivalents of H_2SO_3 will be required to reduce a solution containing 4.60 grams of $Cr_2O_7^{-2}$ ions? The reaction that occurs is:

$$Cr_2O_7^{-2} + H_2SO_3 = Cr^{+2} + SO_4^{-2}$$

8. How many equivalents of Fe^{+3} ions can be reduced to Fe^{+2} by 3 gram ions of S^{-2} ions? The reaction that occurs is:

$$Fe^{-3} + S^{-2} = Fe^{+2} + S$$

ANALYSIS OF VECTOR QUANTITIES

Characteristics of Vector Quantities

Trigonometric Resolution of Vector Quantities

Graphic Resolution of Vector Quantities

Analysis of Vector Quantities

Resource Materials

CHARACTERISTICS OF VECTOR QUANTITIES

Required Reading: Modern Physics, pages 29-35

Recommended Reading: Introductory General Physics, #530 Wi, pages 103-109 and pages 136-138

Vectors: Directed Quantities, Basic Science Series, #200-3, Mechanics, Alexander Efron

QUESTIONS FOR CONSIDERATION:

1. What characteristics distinquish vector quantities from scalar quantities? What is a physical quantity? Are physical quantities vectors or scalars? Is the physical quantity which represents spatial dimension a vector or scalar?

2. Explain how it is possible for the sum of vector A, 2 units, and vector B, 4 units, to equal any numerical value from 0 to 6?

3. Describe the vector or scalar property of the physical quantity resulting from the following:
   a. the product of two parallel vectors -
   b. the product of two vectors, perpendicular -
   c. the division of two parallel vectors -
   d. the division of a vector by a scalar -

4. Classify each of the following as vector or scalar quantities:
   a. force
   b. weight
   c. velocity
   d. area
   e. volume
   f. speed
   g. time
   h. density
   i. surface tension
   j. tensile strength
   k. elastic limit
   l. work

5. Describe two procedures by which it is possible to determine the sum of two or more vector quantities.

CHARACTERISTICS OF VECTOR QUANTITIES

I. Classification of Physical Quantities

  A. Scalar

  B. Vector

II. Rules for Establishing the Vector Properties of Defined Physical Quantities

  A. Addition of Vectors

  B. Subtraction of Vectors (a special case of vector addition)

  C. Multiplication of Vectors

    1. scalar products

    2. vector products

    3. vector - scalar products

  D. Division of Vectors (a special case of vector multiplication)

    1. vector - vector division

    2. scalar - scalar division

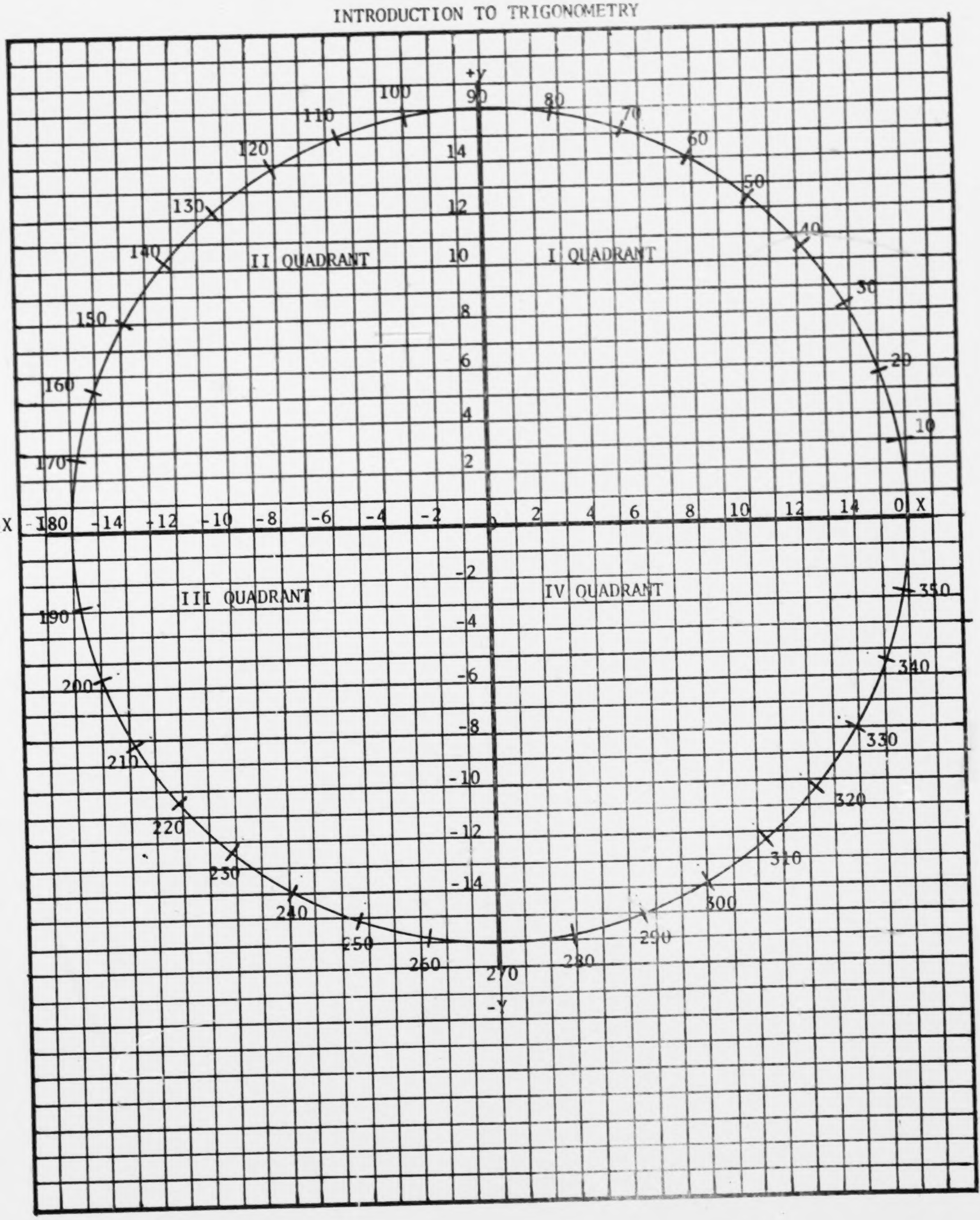
III. Analysis of Vector Quantities

  A. Graphic Resolution of Vectors
    1. rectangular resolution
    2. polygon method
  B. Trigonometric Resolution of Vectors

Physical Quantity	Symbol	Definition	Vector	Scalar	Gravitational System			Absolute System		
					F.P.S.	C.G. S.	M.K.S.	F.P.S.	C.G.S.	M.K.S.

Physical Quantity	Symbol	Definition	Vector	Scalar	Gravitational System			Absolute System		
					F.P.S.	C.G. S.	M.K.S.	F.P.S.	C.G.S.	M.K.S.

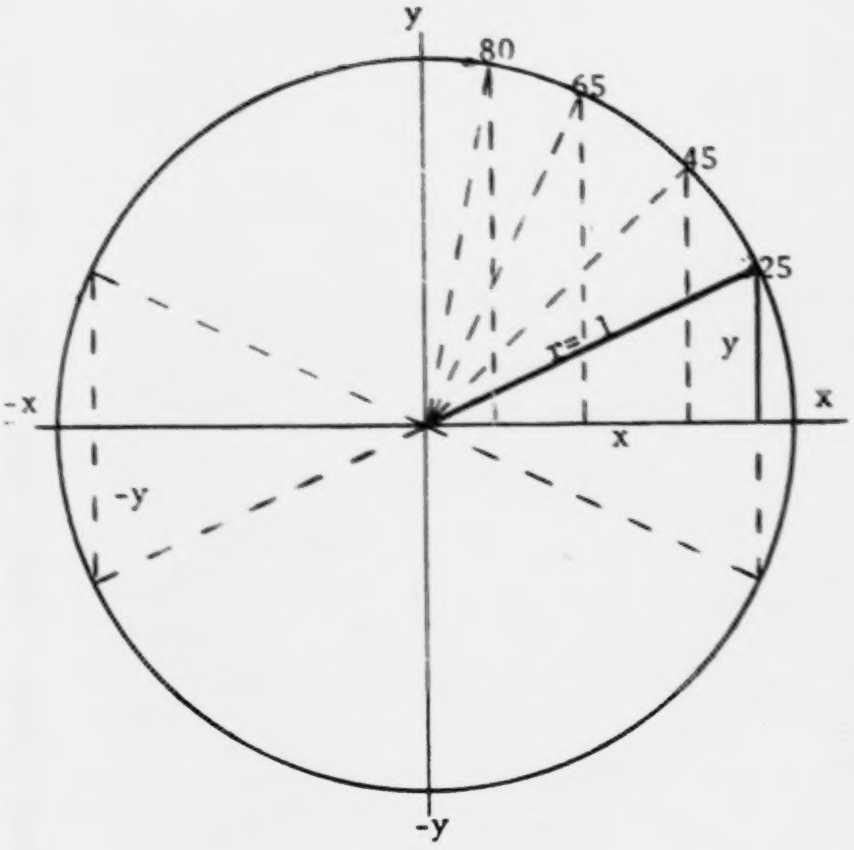
INTRODUCTION TO TRIGONOMETRY


+y
-y
-X
X
I QUADRANT
II QUADRANT
III QUADRANT
IV QUADRANT
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
14
12
10
8
6
4
2
-2
-4
-6
-8
-10
-12
-14
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14

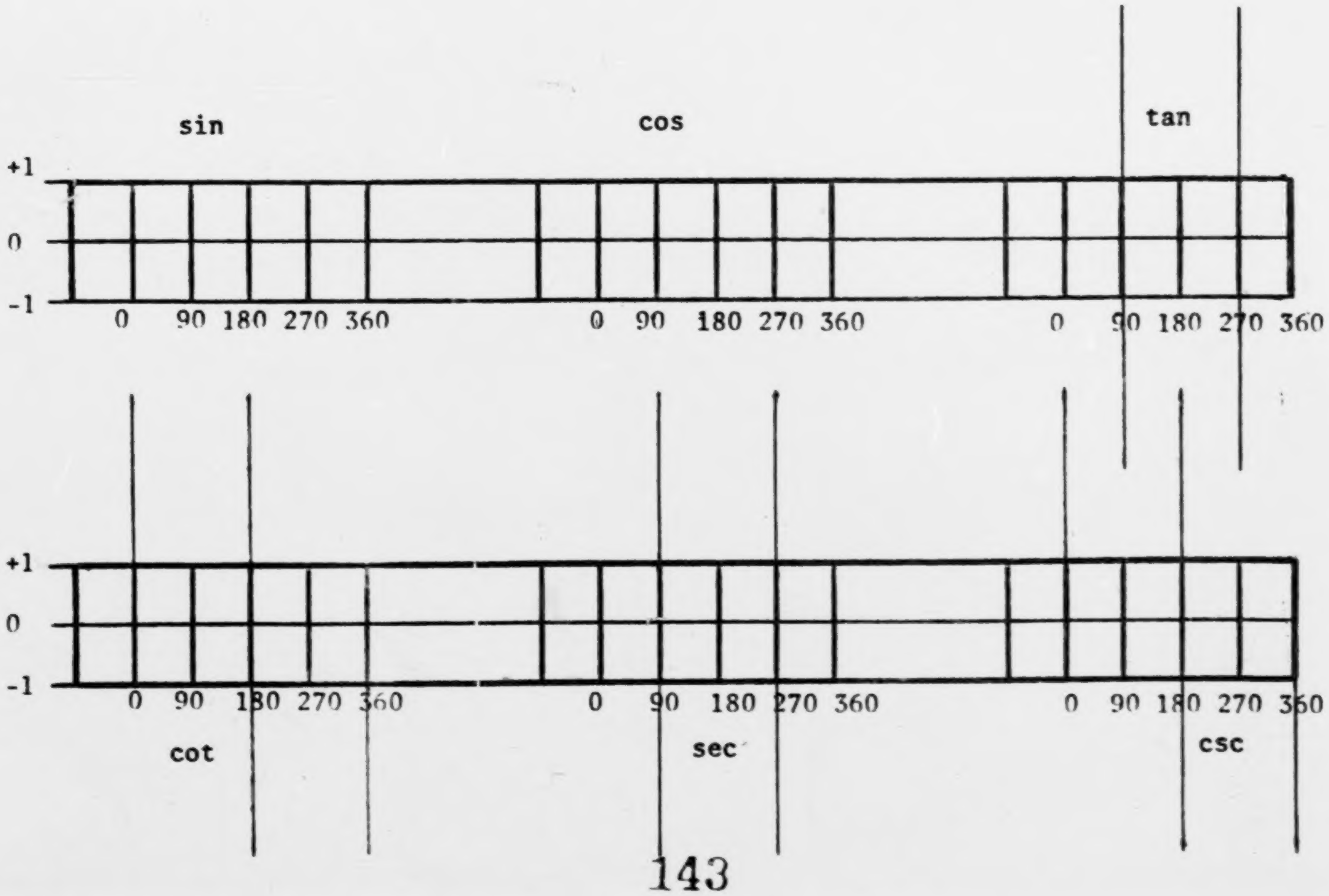
Name________________________________

Science IIIa Hour ____________

Date Due________________________


y
80
65
45
25
r=1
y
x
-x
x
-y
y
-y

	0°	90°	180°	270°	360°
SIN = $\frac{y}{r}$					
COS = $\frac{x}{r}$					
TAN = $\frac{y}{x}$					
COT = $\frac{x}{y}$					
SEC = $\frac{r}{x}$					
CSC = $\frac{r}{y}$					


sin
cos
tan
+1
0
-1
0 90 180 270 360
0 90 180 270 360
0 90 180 270 360
+1
0
-1
0 90 180 270 360
0 90 180 270 360
0 90 180 270 360
cot
sec
csc

Problem Exercise

Name ______________________________

Science IIIA Hour _____

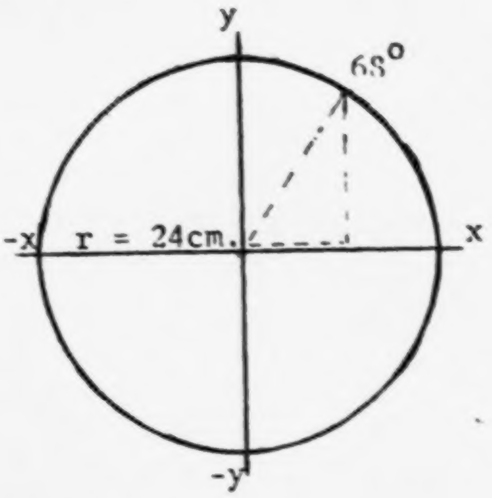
Date ______________________________

RESOLUTION OF VECTOR COMPONENTS BY TRIGONOMETRY

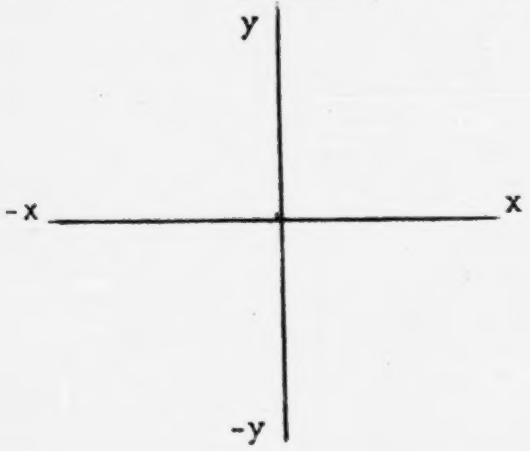
1. Calculate the horizontal (x) and verticle (y) components for the right triangle inscribed in the circle at the right.

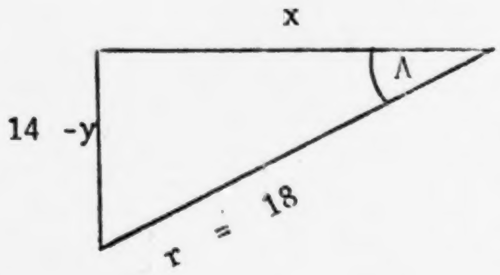
x = __________

y = __________



2. Calculate angle A and the magnitude of side x for a right triangle where r = 18 cm. and y = -14 cm.





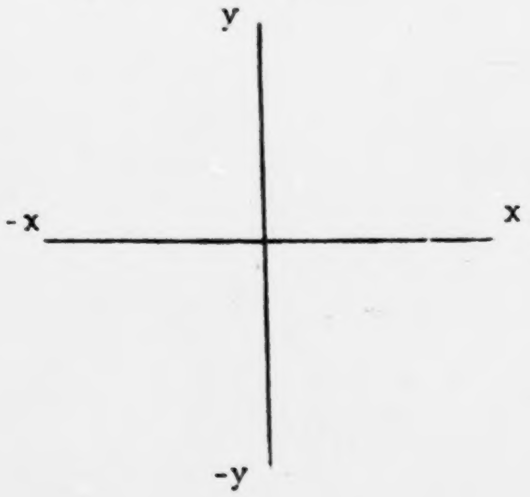
angle A = __________

side x = __________

3. A force of 40 lbs. acts upon a point at an angle of 64^0. Calculate the x and y components for this force.

x = __________

y = __________



Analysis of Vector Quantities

TRIGONOMETRIC ANALYSIS OF VECTOR QUANTITIES

(Determination of Resultants)

INTRODUCTION:

Any procedure used to determine the vector sum of a number of quantities associated with a particular system must take into account both the magnitude and the direction of each vector quantity acting within the system. The vector sum of all of the vector quantities acting within a system is called the RESULTANT. A resultant is also a vector quantity and as such has both a magnitude and a direction.

The resultant for any system of vector quantities may be calculated by resolving each separate vector within the system into its horizontal (x) and vertical (y) components. One the x and y components for each separate vector quantity have been determined the total x and y for the system can be calculated by algebraic addition. Remember, vectors which are parallel can be added algebraically. The summation of the x and y components of the separate vector quantities in the system can then be used to determine both the magnitude and direction of the resultant.

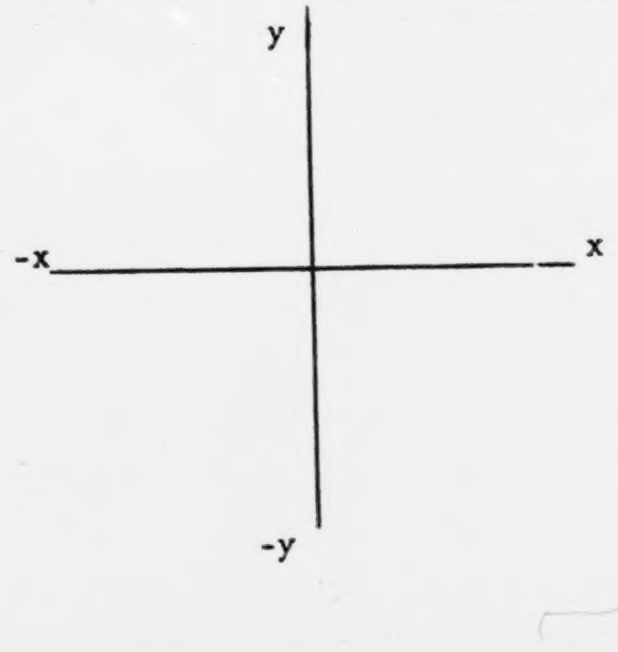
The most accurate method of determining a resultant is by trigonometric analysis. The x and y components of each vector are calculated by use of the sine and cosine functions. After determining the algebraic sum of the x and y components the direction of the resultant is calculated by using the tangent function and the tables which give a numerical equivalent for all ratios of x/y, in degrees.

Having established the angle of the resultant, its magnitude can be calculated by taking either the sine of the angle of the resultant, $\sin\theta = y/r$, and solving for r or using the cosine of the angle, $\cos\theta = x/r$, and solving for r.

Assume that three forces act upon a single point.

F_1 equals 100 g at 40^o
F_2 equals 60 g at 160^o
F_3 equals 200 g at 290^o

Calculate the **magnitude and direction of the resultant force.**



	x	y
F_1		
F_2		
F_3		

$\sin\theta = y/r$ $\cos\theta = x/r$

$\tan\theta = y/x =$

Problem Exercise

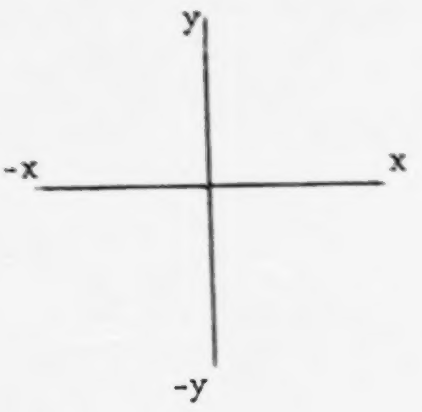
Name ______________________

Science IIIA Hour _____

Date ______________________

ANALYSIS OF VECTOR QUANTITIES BY TRIGONOMETRY

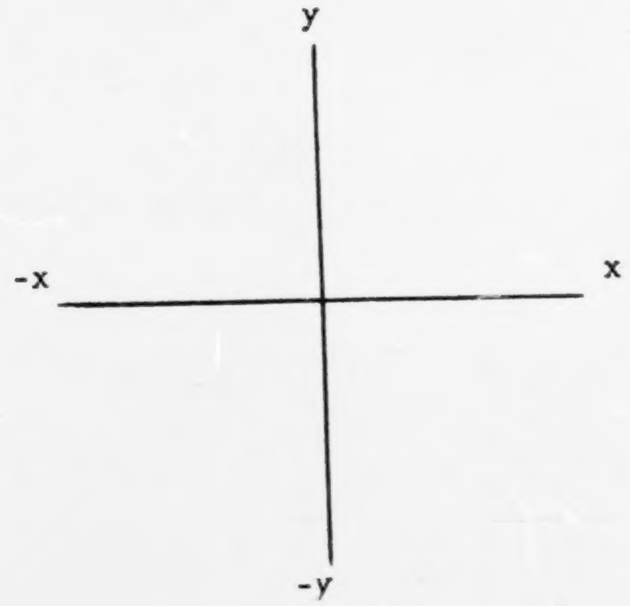
1. Three forces act simultaneously and at the same point on a body. F_1 = 4.2 kg at 30°, F_2 = 1.8 kg at 20°, F_3 = 6.4 kg at 330°. Calculate the magnitude and direction of the resultant force.



	x	y
F_1		
F_2		
F_3		

RF = ______________

2. A 727 jet airliner traveling with a velocity of 640 miles/hour and a heading of 146° encounters a wind velocity of 60 miles/hour from 110°. Calculate the resultant velocity of the aircraft.



	x	y

R vel. = ______________

Analysis of Vector Quantities

GRAPHIC ANALYSIS OF VECTOR QUANTITIES

INTRODUCTION:

Resultants in systems involving vector quantities may also be determined graphically. Graphic solution for resultants are likely to be less accurate than those obtained by trigonometric methods. However, the graphic technique has the advantage of being much faster.

In the graphic approach to problem solving it is not neccessary to resolve the individual vectors into x and y components. A direct addition is possible because both the magnitude and the direction of each vector quantity is taken into account in the vector drawing.

I. Types of Graphic Solutions

  A. **Parallelogram Method**

  B. Polygon Method

II. **Techniques of Graphic Solutions**

  A. Choice of Scale

  B. **Significance** of "Start" and "End" Points

Problem Exercise

Name ______________________

Science IIIA Hour _____

Date ______________________

DETERMINATION OF RESULTANTS BY GRAPHIC SOLUTION

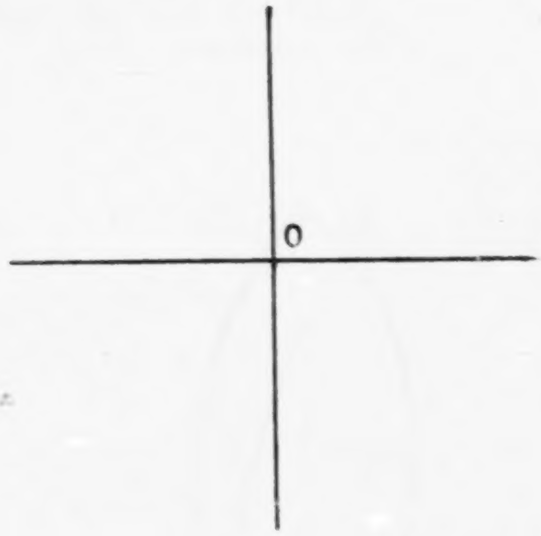
1. Four forces act upon point O,

F_1 = 100 g at 30°
F_2 = 200 g at 70°
F_3 = 350 g at 300°
F_4 = 150 g at 140°

Determine the resultant force.

RF = ______________

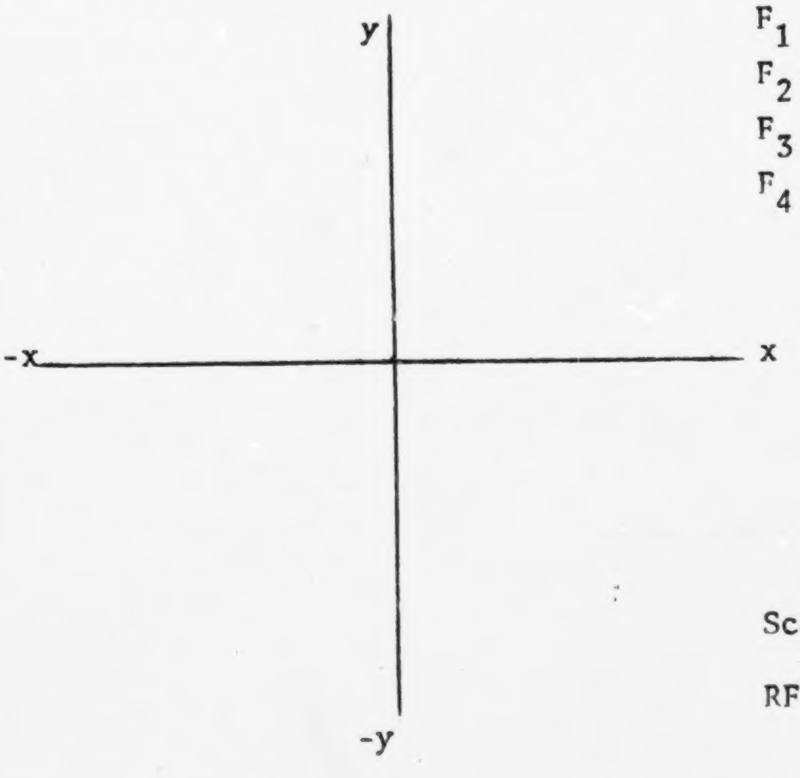
*Select the force vectors in an order which will keep your drawing on the page.



Scale = ________

2. Determine the resultant force for the following:

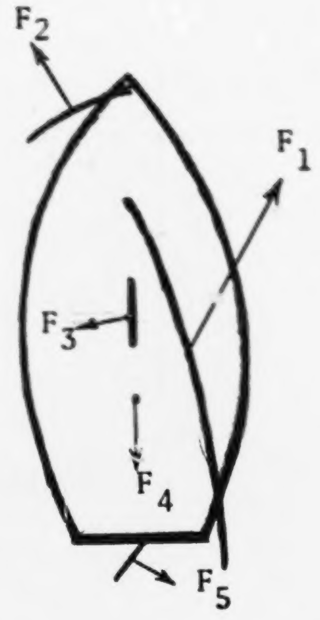
F_1 = 1200 lb, 18°
F_2 = 4000 lb, 210°
F_3 = 5600 lb, 165°
F_4 = 2400 lb, 340°

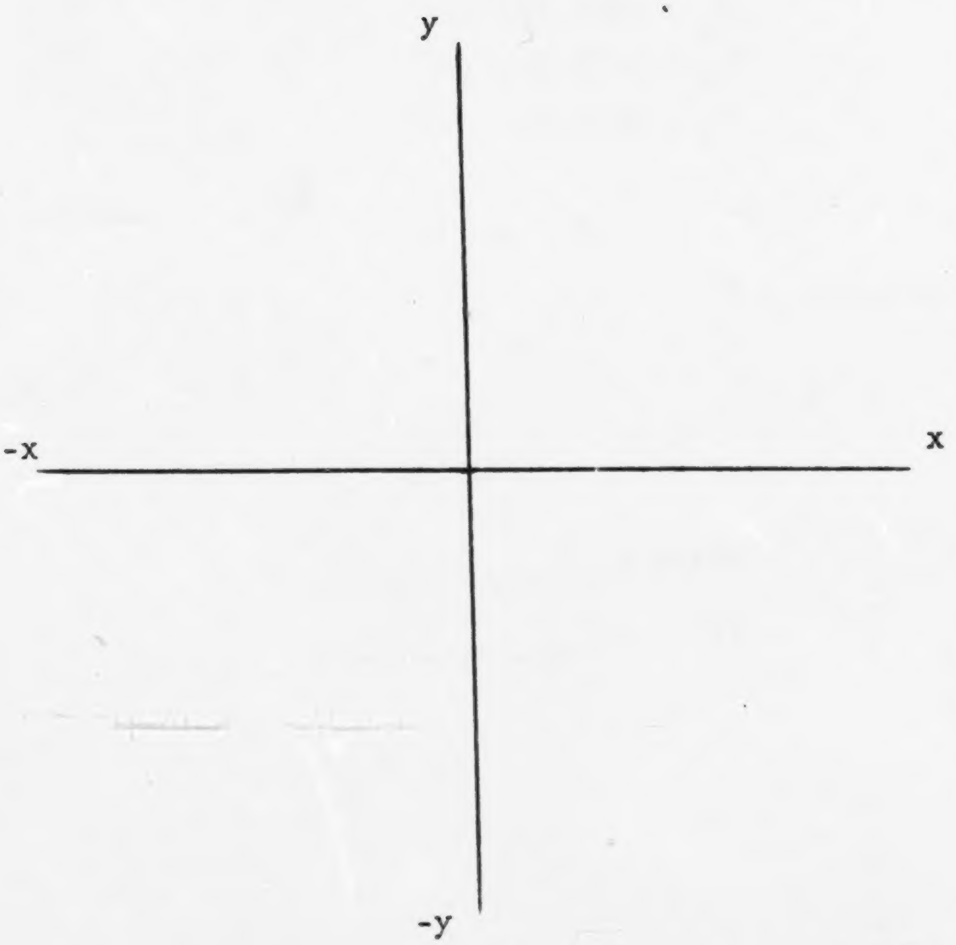


Scale = ______________

RF = ______________

3. The following forces were found to be acting simultaneously upon a sailboat as it was turning into the wind. F_1 on the main sail = 400 lbs at 60°, F_2 on the jib equal 100 lbs at 120°.
   F_3 equaled a force of 150 lbs at 190° resulting from the water current against the centerboard and F_4, the resistance of the hull moving through the water, equaled 80 lbs at 270 degrees and F_5 = a force of 60 lbs at 300° acting upon the rudder.
   Calculate the resultant force acting upon the boat and the direction of its movement.





TRIGONOMETRIC FUNCTIONS

SIN							
ANGLE	0′	12′	24′	36′	48′	60′	
0	.0000	0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	0384	.0419	.0454	.0488	.0523	87
3	.0523	.0558	.0593	.0628	.0663	.0698	86
4	.0698	.0732	.0767	.0802	.0837	.0872	85
5	.0872	.0906	.0941	.0976	.1011	.1045	84
6	.1045	.1080	.1115	.1149	.1184	.1219	83
7	.1219	.1253	.1288	.1323	.1357	.1392	82
8	.1392	.1426	.1461	.1495	.1530	.1564	81
9	.1564	.1599	.1633	.1668	.1702	.1736	80
10	.1736	.1771	.1805	.1840	.1874	.1908	79
11	.1908	.1942	.1977	.2011	.2045	.2079	78
12	.2079	.2113	.2147	.2181	.2215	.2250	77
13	.2250	.2284	.2317	.2351	.2385	.2419	76
14	.2419	.2453	.2487	.2521	.2554	.2588	75
15	.2588	.2622	.2656	.2689	.2723	.2756	74
16	.2756	.2790	.2823	.2857	.2890	.2924	73
17	.2924	.2957	.2990	.3024	.3057	.3090	72
18	.3090	.3123	.3156	.3190	.3223	.3256	71
19	.3256	.3289	.3322	.3355	.3387	.3420	70
20	.3420	.3453	.3486	.3518	.3551	.3584	69
21	.3584	.3616	.3649	.3681	.3714	.3746	68
22	.3746	.3778	.3811	.3843	.3875	.3907	67
23	.3907	.3939	.3971	.4003	.4035	.4067	66
24	.4067	.4099	.4131	.4163	.4195	.4226	65
25	.4226	.4258	.4289	.4321	.4352	.4384	64
26	.4384	.4415	.4446	.4478	.4509	.4540	63
27	.4540	.4571	.4602	.4633	.4664	.4695	62
28	.4695	.4726	.4756	.4787	.4818	.4848	61
29	.4848	.4879	.4909	.4939	.4970	.5000	60
30	.5000	.5030	.5060	.5090	.5120	.5150	59
31	.5150	.5180	.5210	.5240	.5270	.5299	58
32	.5299	.5329	.5358	.5388	.5417	.5446	57
33	.5446	.5476	.5505	.5534	.5563	.5592	56
34	.5592	.5621	.5650	.5678	.5707	.5736	55
35	.5736	.5764	.5793	.5821	.5850	.5878	54
36	.5878	.5906	.5934	.5962	.5990	.6018	53
37	.6018	.6046	.6074	.6101	.6129	.6157	52
38	.6157	.6184	.6211	.6239	.6266	.6293	51
39	.6293	.6320	.6347	.6374	.6401	.6428	50
40	.6428	.6455	.6481	.6508	.6534	.6561	49
41	.6561	.6587	.6613	.6639	.6665	.6691	48
42	.6691	.6717	.6743	.6769	.6794	.6820	47
43	.6820	.6845	.6871	.6896	.6921	.6947	46
44	.6947	.6972	.6997	.7022	.7046	.7071	45
45	.7071	.7096	.7120	.7145	.7169	.7193	44
46	.7193	.7218	.7242	.7266	.7290	.7314	43
47	.7314	.7337	.7361	.7385	.7408	.7431	42
48	.7431	.7455	.7478	.7501	.7524	.7547	41
49	.7547	.7570	.7593	.7615	.7638	.7660	40
50	.7660	.7683	.7705	.7727	.7749	.7771	39
51	.7771	.7793	.7815	.7837	.7859	.7880	38
52	.7880	.7902	.7923	.7944	.7965	.7986	37
53	.7986	.8007	.8028	.8049	.8070	.8090	36
54	.8090	.8111	.8131	.8151	.8171	.8192	35
55	.8192	.8211	.8231	.8251	.8271	.8290	34
56	.8290	.8310	.8329	.8348	.8368	.8387	33
57	.8387	.8406	.8425	.8443	.8462	.8480	32
58	.8480	.8499	.8517	.8536	.8554	.8572	31
59	.8572	.8590	.8607	.8625	.8643	.8660	30
60	.8660	.8678	.8695	.8712	.8729	.8746	29
61	.8746	.8763	.8780	.8796	.8813	.8829	28
62	.8829	.8846	.8862	.8878	.8894	.8910	27
63	.8910	.8926	.8942	.8957	.8973	.8988	26
64	.8988	.9003	.9018	.9033	.9048	.9063	25
65	.9063	.9078	.9092	.9107	.9121	.9135	24
66	.9135	.9150	.9164	.9178	.9191	.9205	23
67	.9205	.9219	.9232	.9245	.9259	.9272	22
68	.9272	.9285	.9298	.9311	.9323	.9336	21
69	.9336	.9348	.9361	.9373	.9385	.9397	20
70	.9397	.9409	.9421	.9432	.9444	.9455	19
71	.9455	.9466	.9478	.9489	.9500	.9511	18
72	.9511	.9521	.9532	.9542	.9553	.9563	17
73	.9563	.9573	.9583	.9593	.9603	.9613	16
74	.9613	.9622	.9632	.9641	.9650	.9659	15
75	.9659	.9668	.9677	.9686	.9694	.9703	14
76	.9703	.9711	.9720	.9728	.9736	.9744	13
77	.9744	.9751	.9759	.9767	.9774	.9781	12
78	.9781	.9789	.9796	.9803	.9810	.9816	11
79	.9816	.9823	.9829	.9836	.9842	.9848	10
80	.9848	.9854	.9860	.9866	.9871	.9877	9
81	.9877	.9882	.9888	.9893	.9898	.9903	8
82	.9903	.9907	.9912	.9917	.9921	.9925	7
83	.9925	.9930	.9934	.9938	.9942	.9945	6
84	.9945	.9949	.9952	.9956	.9959	.9962	5
85	.9962	.9965	.9968	.9971	.9973	.9976	4
86	.9976	.9978	.9980	.9982	.9984	.9986	3
87	.9986	.9988	.9990	.9991	.9993	.9994	2
88	.9994	.9995	.9996	.9997	.9998	.9998	1
89	.9998	.9999	.9999	1.000	1.000	1.000	0
90	1.000						
	60′	48′	36′	24′	12′	0′	ANGLE
						COS	

TAN							
ANGLE	0′	12′	24′	36′	48′	60′	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0489	.0524	87
3	.0524	.0559	.0594	.0629	.0664	.0699	86
4	.0699	.0734	.0769	.0805	.0840	.0875	85
5	.0875	.0910	.0945	.0981	.1016	.1051	84
6	.1051	.1086	.1122	.1157	.1192	.1228	83
7	.1228	.1263	.1299	.1334	.1370	.1405	82
8	.1405	.1441	.1477	.1512	.1548	.1584	81
9	.1584	.1620	.1655	.1691	.1727	.1763	80
10	.1763	.1799	.1835	.1871	.1908	.1944	79
11	.1944	.1980	.2016	.2053	.2089	.2126	78
12	.2126	.2162	.2199	.2235	.2272	.2309	77
13	.2309	.2345	.2382	.2419	.2456	.2493	76
14	.2493	.2530	.2568	.2605	.2642	.2679	75
15	.2679	.2717	.2754	.2792	.2830	.2867	74
16	.2867	.2905	.2943	.2981	.3019	.3057	73
17	.3057	.3096	.3134	.3172	.3211	.3249	72
18	.3249	.3288	.3327	.3365	.3404	.3443	71
19	.3443	.3482	.3522	.3561	.3600	.3640	70
20	.3640	.3679	.3719	.3759	.3799	.3839	69
21	.3839	.3879	.3919	.3959	.4000	.4040	68
22	.4040	.4081	.4122	.4163	.4204	.4245	67
23	.4245	.4286	.4327	.4369	.4411	.4452	66
24	.4452	.4494	.4536	.4578	.4621	.4663	65
25	.4663	.4706	.4748	.4791	.4834	.4877	64
26	.4877	.4921	.4964	.5008	.5051	.5095	63
27	.5095	.5139	.5184	.5228	.5272	.5317	62
28	.5317	.5362	.5407	.5452	.5498	.5543	61
29	.5543	.5589	.5635	.5681	.5727	.5774	60
30	.5774	.5820	.5867	.5914	.5961	.6009	59
31	.6009	.6056	.6104	.6152	.6200	.6249	58
32	.6249	.6297	.6346	.6395	.6445	.6494	57
33	.6494	.6544	.6594	.6644	.6694	.6745	56
34	.6745	.6796	.6847	.6899	.6950	.7002	55
35	.7002	.7054	.7107	.7159	.7212	.7265	54
36	.7265	.7319	.7373	.7427	.7481	.7536	53
37	.7536	.7590	.7646	.7701	.7757	.7813	52
38	.7813	.7869	.7926	.7983	.8040	.8098	51
39	.8098	.8156	.8214	.8273	.8332	.8391	50
40	.8391	.8451	.8511	.8571	.8632	.8693	49
41	.8693	.8754	.8816	.8878	.8941	.9004	48
42	.9004	.9067	.9131	.9195	.9260	.9325	47
43	.9325	.9391	.9457	.9523	.9590	.9657	46
44	.9657	.9725	.9793	.9861	.9930	1.000	45
45	1.000	1.007	1.014	1.021	1.028	1.035	44
46	1.036	1.043	1.050	1.058	1.065	1.072	43
47	1.072	1.080	1.088	1.095	1.103	1.111	42
48	1.111	1.118	1.126	1.134	1.142	1.150	41
49	1.150	1.159	1.167	1.175	1.183	1.192	40
50	1.192	1.200	1.209	1.217	1.226	1.235	39
51	1.235	1.244	1.253	1.262	1.271	1.280	38
52	1.280	1.289	1.299	1.308	1.318	1.327	37
53	1.327	1.337	1.347	1.356	1.366	1.376	36
54	1.376	1.387	1.397	1.407	1.418	1.428	35
55	1.428	1.439	1.450	1.461	1.472	1.483	34
56	1.483	1.494	1.505	1.517	1.528	1.540	33
57	1.540	1.552	1.564	1.576	1.588	1.600	32
58	1.600	1.613	1.626	1.638	1.651	1.664	31
59	1.664	1.678	1.691	1.705	1.718	1.732	30
60	1.732	1.746	1.760	1.775	1.789	1.804	29
61	1.804	1.819	1.834	1.850	1.865	1.881	28
62	1.881	1.897	1.913	1.929	1.946	1.963	27
63	1.963	1.980	1.997	2.015	2.032	2.050	26
64	2.050	2.069	2.087	2.106	2.125	2.145	25
65	2.145	2.164	2.184	2.205	2.225	2.246	24
66	2.246	2.267	2.289	2.311	2.333	2.356	23
67	2.356	2.379	2.402	2.426	2.450	2.475	22
68	2.475	2.500	2.526	2.552	2.578	2.605	21
69	2.605	2.633	2.661	2.689	2.718	2.748	20
70	2.748	2.778	2.808	2.840	2.872	2.904	19
71	2.904	2.938	2.971	3.006	3.042	3.078	18
72	3.078	3.115	3.152	3.191	3.231	3.271	17
73	3.271	3.312	3.354	3.398	3.442	3.487	16
74	3.487	3.534	3.582	3.631	3.681	3.732	15
75	3.732	3.785	3.839	3.895	3.952	4.011	14
76	4.011	4.071	4.134	4.198	4.264	4.332	13
77	4.332	4.402	4.474	4.548	4.625	4.705	12
78	4.705	4.787	4.872	4.959	5.050	5.145	11
79	5.145	5.242	5.344	5.449	5.558	5.671	10
80	5.671	5.789	5.912	6.041	6.174	6.314	9
81	6.314	6.460	6.612	6.772	6.940	7.115	8
82	7.115	7.300	7.495	7.700	7.916	8.144	7
83	8.144	8.386	8.643	8.915	9.205	9.514	6
84	9.514	9.845	10.20	10.58	10.99	11.43	5
85	11.43	11.91	12.43	13.00	13.62	14.30	4
86	14.30	15.06	15.89	16.83	17.89	19.08	3
87	19.08	20.45	22.02	23.86	26.03	28.64	2
88	28.64	31.82	35.80	40.92	47.74	57.29	1
89	57.29	71.62	95.49	143.2	286.5		0
90							
	60′	48′	36′	24′	12′	0′	ANGLE
						COT	

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Catalog No. 592

FOUR - PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

N	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

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Catalog No. 592

TABLE OF COMMON VALENCES

+1		+2		+3	
sodium	Na^{+1}	magnesium	Mg^{+2}	aluminum	Al^{+3}
potassium	K^{+1}	calcium	Ca^{+2}	ferric	Fe^{+3}
hydrogen	H^{+1}	zinc	Zn^{+2}	chromic	Cr^{+3}
cuprous	Cu^{+1}	ferrous	Fe^{+2}		
lithium	Li^{+1}	cupric	Cu^{+2}		
silver	Ag^{+1}	mercuric	Hg^{+2}		
ammonium	$\boxed{NH_4^{+1}}$	nickel	Ni^{+2}		
		barium	Ba^{+2}		
		lead	Pb^{+2}		

-1		-2		-3	
fluoride	F^{-1}	sulfide	S^{-2}	nitride	N^{-3}
chloride	Cl^{-1}	oxide	O^{-2}	phosphate	$\boxed{PO_4^{-3}}$
bromide	Br^{-1}	sulfate	$\boxed{SO_4^{-2}}$		
iodide	I^{-1}	carbonate	$\boxed{CO_3^{-2}}$		
nitrate	$\boxed{NO_3^{-1}}$	sulfite	$\boxed{SO_3^{-2}}$		
chlorate	$\boxed{ClO_3^{-1}}$	peroxide	$\boxed{O_2^{-2}}$		
hydroxide	$\boxed{OH^{-1}}$				
bicarbonate	$\boxed{HCO_3^{-1}}$				
nitrite	$\boxed{NO_2^{-1}}$				
acetate	$\boxed{C_2H_3O_2^{-1}}$				
bisulfate	$\boxed{HSO_4^{-1}}$				

$\boxed{}$ denotes radical

PERIODIC CHART

s   d

TRANSITION

LIGHT METALS

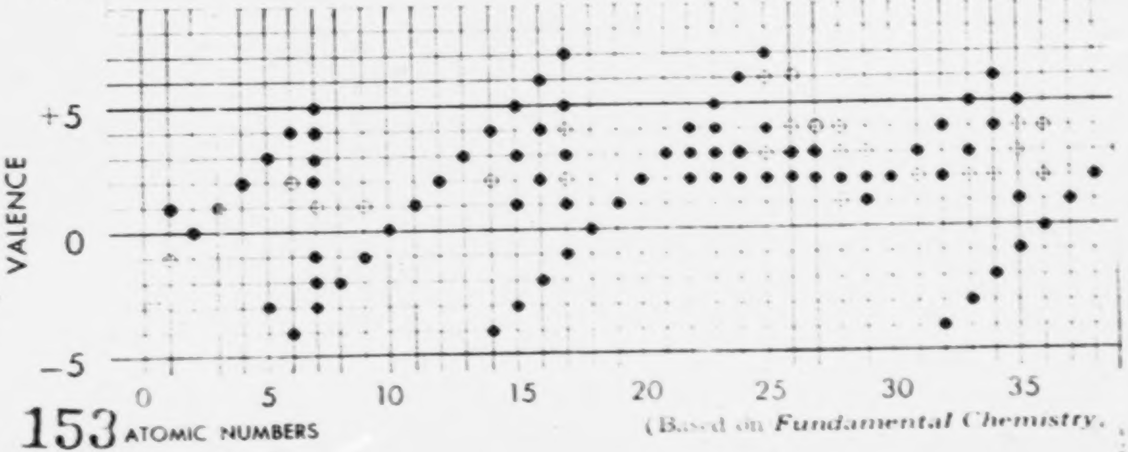
SHELLS PRINCIPAL QUANTUM No. *n*	X-RAY NOTATION	I A	II A	III B	B	V B	VI B	VII B
1	K	1 1 H 1.00797						
2	L	2 1 3 Li 6.939	2 2 4 Be 9.0122					
3	M	2 8 1 11 Na 22.9898	2 8 2 12 Mg 24.312					
4	N	2 8 8 1 19 K 39.102	2 8 8 2 20 Ca 40.08	2 8 9 2 21 Sc 44.956	2 8 10 2 22 Ti 47.90	2 8 11 2 23 V 50.942	2 8 13 1 24 Cr 51.996	2 8 13 2 25 Mn 54.9380
5	O	2 8 18 8 1 37 Rb 85.47	2 8 18 8 2 38 Sr 87.62	2 8 18 9 2 39 Y 88.905	2 8 18 10 2 40 Zr 91.22	2 8 18 12 1 41 Nb 92.906	2 8 18 13 1 42 Mo 95.94	2 8 18 13 2 43 Tc (99)
6	P	2 8 18 18 8 1 55 Cs 132.905	2 8 18 18 8 2 56 Ba 137.34	57-71 See Lanthanide Series	2 8 18 32 10 2 72 Hf 178.49	2 8 18 32 11 2 73 Ta 180.948	2 8 18 32 12 2 74 W 183.85	2 8 18 32 13 2 75 Re 186.2
7	Q	2 8 18 32 18 8 1 87 Fr (223)	2 8 18 32 18 8 2 88 Ra 226	89-100 See Actinide Series				

6	P	LANTHANIDE SERIES (Rare Earth Elements)
7	Q	ACTINIDE SERIES

NOTE: A value given in parentheses denotes the mass number of the isotope of the longest known half-life, or of the best known one.

*The brackets are meant to indicate only the general order of subshell filling. The filling of subshells is not completely regular, as is emphasized by the use of red ink to denote shells which have electron populations different from the preceding element. In the case of He, subshell population is not by itself indicative of chemical behavior, and that element is therefore included in the inert gas group, even though helium possesses no p-electrons.

Open circles represent valence states of minor importance, or those



(Based on *Fundamental Chemistry*,

OF THE ELEMENTS

REVISED, 1964

p

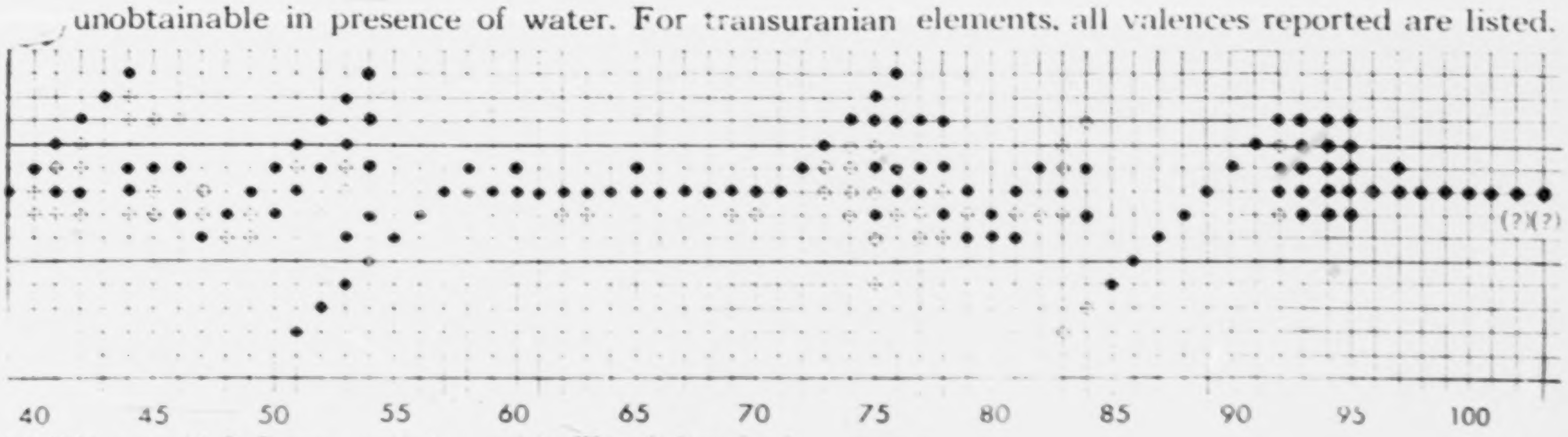
HEAVY METALS

NON METALS

	VIII		VIII		VIII		I B		II B		III A		IV A		V A		VI A		VII A		INERT GASES
																				2	2 He 4.0026
										2 3	5 B 10.811	2 4	6 C 12.01115	2 5	7 N 14.0067	2 6	8 O 15.9994	2 7	9 F 18.9984	2 8	10 Ne 20.183
										2 8 3	13 Al 26.9815	2 8 4	14 Si 28.086	2 8 5	15 P 30.9738	2 8 6	16 S 32.064	2 8 7	17 Cl 35.453	2 8 8	18 Ar 39.948
2 8 14 2	26 Fe 55.847	2 8 15 2	27 Co 58.9332	2 8 16 2	28 Ni 58.71	2 8 18 1	29 Cu 63.54	2 8 18 2	30 Zn 65.37	2 8 18 3	31 Ga 69.72	2 8 18 4	32 Ge 72.59	2 8 18 5	33 As 74.9216	2 8 18 6	34 Se 78.96	2 8 18 7	35 Br 79.909	2 8 18 8	36 Kr 83.80
2 8 18 15 1	44 Ru 101.07	2 8 18 16 1	45 Rh 102.905	2 8 18 18	46 Pd 106.4	2 8 18 18 1	47 Ag 107.870	2 8 18 18 2	48 Cd 112.40	2 8 18 18 3	49 In 114.82	2 8 18 18 4	50 Sn 118.69	2 8 18 18 5	51 Sb 121.75	2 8 18 18 6	52 Te 127.60	2 8 18 18 7	53 I 126.9044	2 8 18 18 8	54 Xe 131.30
2 8 18 32 14 2	76 Os 190.2	2 8 18 32 15 2	77 Ir 192.2	2 8 18 32 17 1	78 Pt 195.09	2 8 18 32 18 1	79 Au 196.967	2 8 18 32 18 2	80 Hg 200.59	2 8 18 32 18 3	81 Tl 204.37	2 8 18 32 18 4	82 Pb 207.19	2 8 18 32 18 5	83 Bi 208.980	2 8 18 32 18 6	84 Po (210)	2 8 18 32 18 7	85 At (210)	2 8 18 32 18 8	86 Rn (222)

	d		f		f		f		f		f		f		f		f		f		f		f		f		f		f
2 8 18 18 9 2	57 La 138.91	2 8 18 19 9 2	58 Ce 140.12	2 8 18 21 8 2	59 Pr 140.907	2 8 18 22 8 2	60 Nd 144.24	2 8 18 23 8 2	61 Pm (147)	2 8 18 24 8 2	62 Sm 150.35	2 8 18 25 8 2	63 Eu 151.96	2 8 18 25 9 2	64 Gd 157.25	2 8 18 26 9 2	65 Tb 158.924	2 8 18 28 8 2	66 Dy 162.50	2 8 18 29 8 2	67 Ho 164.930	2 8 18 30 8 2	68 Er 167.26	2 8 18 31 8 2	69 Tm 168.934	2 8 18 32 8 2	70 Yb 173.04	2 8 18 32 9 2	71 Lu 174.97
2 8 18 32 18 9 2	89 Ac (227)	2 8 18 32 18 10 2	90 Th 232.038	2 8 18 32 20 9 2	91 Pa (231)	2 8 18 32 21 9 2	92 U 238.03	2 8 18 32 22 9 2	93 Np (237)	2 8 18 32 23 9 2	94 Pu (244)	2 8 18 32 24 9 2	95 Am (243)	2 8 18 32 25 9 2	96 Cm (247)	2 8 18 32 26 9 2	97 Bk (247)	2 8 18 32 27 9 2	98 Cf (251)	2 8 18 32 28 9 2	99 Es (254)	2 8 18 32 29 9 2	100 Fm (253)	2 8 18 32 30 9 2	101 Md (256)		102 No (254)		103 Lw (257)

unobtainable in presence of water. For transuranian elements, all valences reported are listed.



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Carl H. Pfeiffer
Wisconsin State Department of Education

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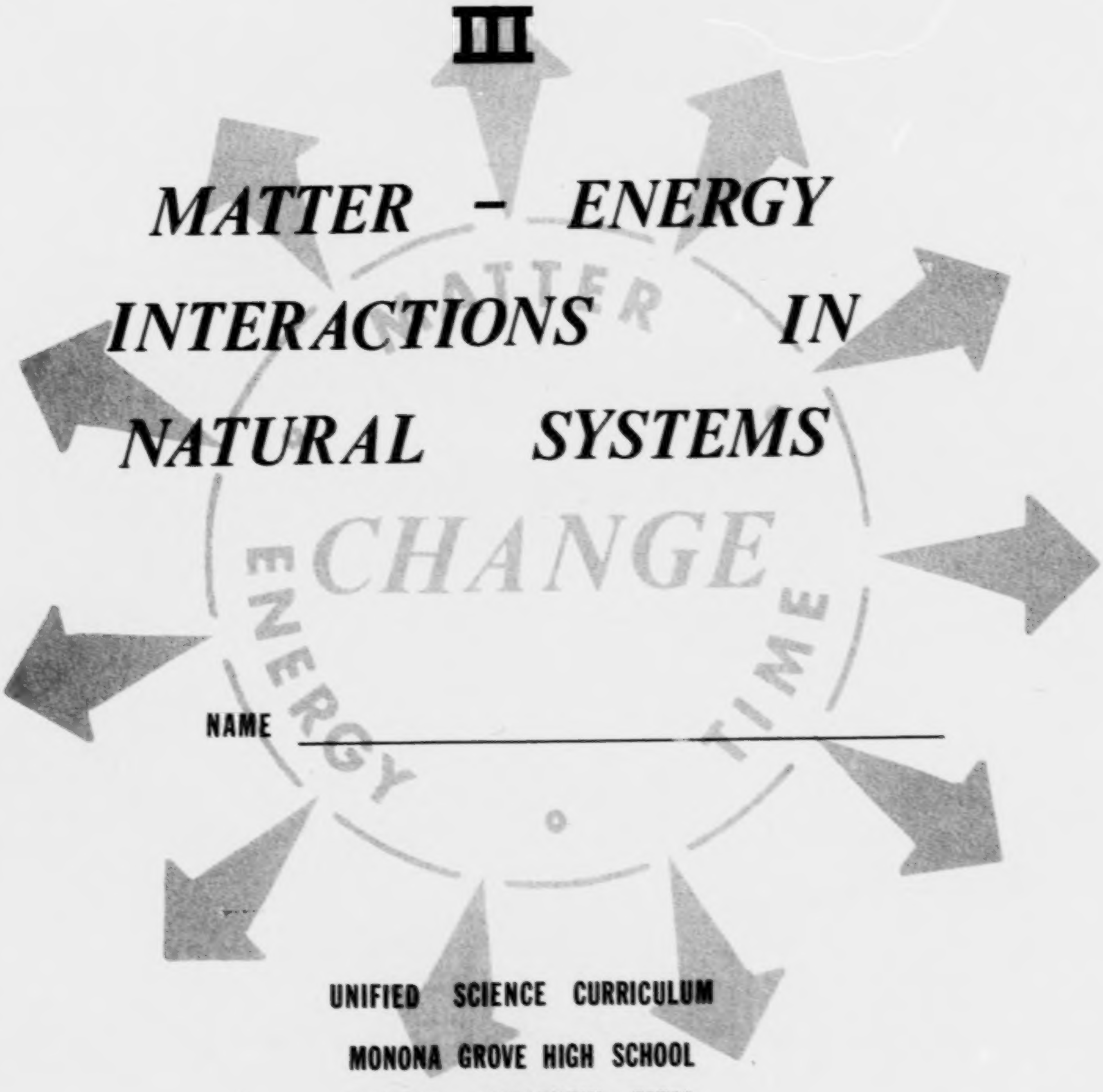
SCIENCE

III

MATTER - ENERGY INTERACTIONS IN NATURAL SYSTEMS



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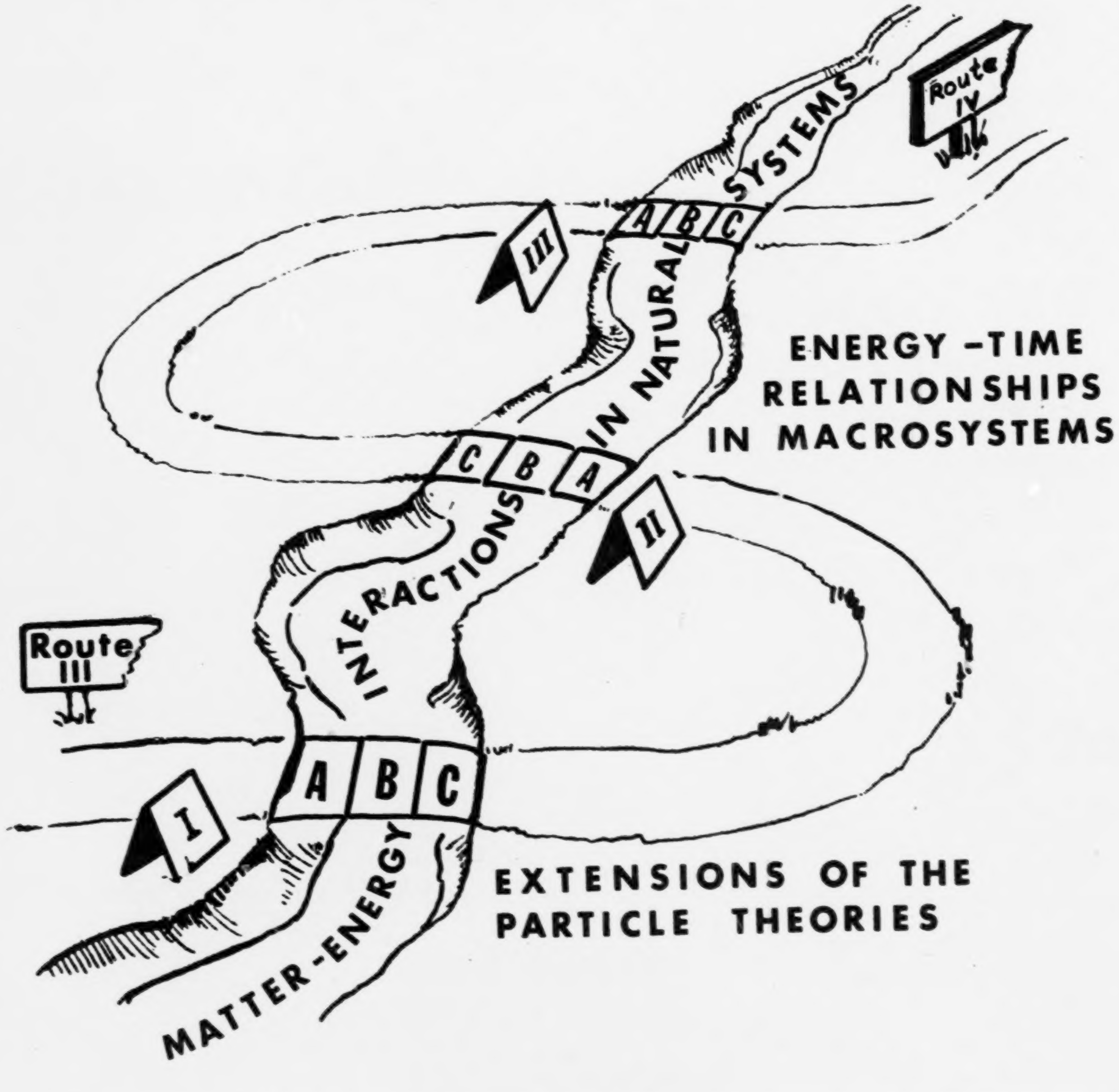
Route IV
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SYSTEMS
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IN NATURAL
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I
EXTENSIONS OF THE PARTICLE THEORIES
MATTER-ENERGY

A. Analysis of Vector Quantities

B. Interactions in Static Equilibrium Systems

C. Interactions in Dynamic Systems

Energy - Time Relationships in Macrosystems (Continued)
Science IIIA - Book II

INTERACTIONS IN STATIC EQUILIBRIUM SYSTEMS

Equilibrium Systems with Forces Acting at One Point

Equilibrium Systems with Forces Acting at More Than One Point

TRIGONOMETRIC FUNCTIONS

ANGLE	SIN 0′	12′	24′	36′	48′	60′	
0	.0000	0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	0384	.0419	.0454	.0488	.0523	87
3	.0523	.0558	.0593	.0628	.0663	.0698	86
4	.0698	.0732	.0767	.0802	.0837	.0872	85
5	.0872	.0906	.0941	.0976	.1011	.1045	84
6	.1045	.1080	.1115	.1149	.1184	.1219	83
7	.1219	.1253	.1288	.1323	.1357	.1392	82
8	.1392	.1426	.1461	.1495	.1530	.1564	81
9	.1564	.1599	.1633	.1668	.1702	.1736	80
10	.1736	.1771	.1805	.1840	.1874	.1908	79
11	.1908	.1942	.1977	.2011	.2045	.2079	78
12	.2079	.2113	.2147	.2181	.2215	.2250	77
13	.2250	.2284	.2317	.2351	.2385	.2419	76
14	.2419	.2453	.2487	.2521	.2554	.2588	75
15	.2588	.2622	.2656	.2689	.2723	.2756	74
16	.2756	.2790	.2823	.2857	.2890	.2924	73
17	.2924	.2957	.2990	.3024	.3057	.3090	72
18	.3090	.3123	.3156	.3190	.3223	.3256	71
19	.3256	.3289	.3322	.3355	.3387	.3420	70
20	.3420	.3453	.3486	.3518	.3551	.3584	69
21	.3584	.3616	.3649	.3681	.3714	.3746	68
22	.3746	.3778	.3811	.3843	.3875	.3907	67
23	.3907	.3939	.3971	.4003	.4035	.4067	66
24	.4067	.4099	.4131	.4163	.4195	.4226	65
25	.4226	.4258	.4289	.4321	.4352	.4384	64
26	.4384	.4415	.4446	.4478	.4509	.4540	63
27	.4540	.4571	.4602	.4633	.4664	.4695	62
28	.4695	.4726	.4756	.4787	.4818	.4848	61
29	.4848	.4879	.4909	.4939	.4970	.5000	60
30	.5000	.5030	.5060	.5090	.5120	.5150	59
31	.5150	.5180	.5210	.5240	.5270	.5299	58
32	.5299	.5329	.5358	.5388	.5417	.5446	57
33	.5446	.5476	.5505	.5534	.5563	.5592	56
34	.5592	.5621	.5650	.5678	.5707	.5736	55
35	.5736	.5764	.5793	.5821	.5850	.5878	54
36	.5878	.5906	.5934	.5962	.5990	.6018	53
37	.6018	.6046	.6074	.6101	.6129	.6157	52
38	.6157	.6184	.6211	.6239	.6266	.6293	51
39	.6293	.6320	.6347	.6374	.6401	.6428	50
40	.6428	.6455	.6481	.6508	.6534	.6561	49
41	.6561	.6587	.6613	.6639	.6665	.6691	48
42	.6691	.6717	.6743	.6769	.6794	.6820	47
43	.6820	.6845	.6871	.6896	.6921	.6947	46
44	.6947	.6972	.6997	.7022	.7046	.7071	45
45	.7071	.7096	.7120	.7145	.7169	.7193	44
	60′	48′	36′	24′	12′	0′ COS	ANGLE

ANGLE	SIN 0′	12′	24′	36′	48′	60′	
46	.7193	.7218	.7242	.7266	.7290	.7314	43
47	.7314	.7337	.7361	.7385	.7408	.7431	42
48	.7431	.7455	.7478	.7501	.7524	.7547	41
49	.7547	.7570	.7593	.7615	.7638	.7660	40
50	.7660	.7683	.7705	.7727	.7749	.7771	39
51	.7771	.7793	.7815	.7837	.7859	.7880	38
52	.7880	.7902	.7923	.7944	.7965	.7986	37
53	.7986	.8007	.8028	.8049	.8070	.8090	36
54	.8090	.8111	.8131	.8151	.8171	.8192	35
55	.8192	.8211	.8231	.8251	.8271	.8290	34
56	.8290	.8310	.8329	.8348	.8368	.8387	33
57	.8387	.8406	.8425	.8443	.8462	.8480	32
58	.8480	.8499	.8517	.8536	.8554	.8572	31
59	.8572	.8590	.8607	.8625	.8643	.8660	30
60	.8660	.8678	.8695	.8712	.8729	.8746	29
61	.8746	.8763	.8780	.8796	.8813	.8829	28
62	.8829	.8846	.8862	.8878	.8894	.8910	27
63	.8910	.8926	.8942	.8957	.8973	.8988	26
64	.8988	.9003	.9018	.9033	.9048	.9063	25
65	.9063	.9078	.9092	.9107	.9121	.9135	24
66	.9135	.9150	.9164	.9178	.9191	.9205	23
67	.9205	.9219	.9232	.9245	.9259	.9272	22
68	.9272	.9285	.9298	.9311	.9323	.9336	21
69	.9336	.9348	.9361	.9373	.9385	.9397	20
70	.9397	.9409	.9421	.9432	.9444	.9455	19
71	.9455	.9466	.9478	.9489	.9500	.9511	18
72	.9511	.9521	.9532	.9542	.9553	.9563	17
73	.9563	.9573	.9583	.9593	.9603	.9613	16
74	.9613	.9622	.9632	.9641	.9650	.9659	15
75	.9659	.9668	.9677	.9686	.9694	.9703	14
76	.9703	.9711	.9720	.9728	.9736	.9744	13
77	.9744	.9751	.9759	.9767	.9774	.9781	12
78	.9781	.9789	.9796	.9803	.9810	.9816	11
79	.9816	.9823	.9829	.9836	.9842	.9848	10
80	.9848	.9854	.9860	.9866	.9871	.9877	9
81	.9877	.9882	.9888	.9893	.9898	.9903	8
82	.9903	.9907	.9912	.9917	.9921	.9925	7
83	.9925	.9930	.9934	.9938	.9942	.9945	6
84	.9945	.9949	.9952	.9956	.9959	.9962	5
85	.9962	.9965	.9968	.9971	.9973	.9976	4
86	.9976	.9978	.9980	.9982	.9984	.9986	3
87	.9986	.9988	.9990	.9991	.9993	.9994	2
88	.9994	.9995	.9996	.9997	.9998	.9998	1
89	.9998	.9999	.9999	1.000	1.000	1.000	0
90	1.000						
	60′	48′	36′	24′	12′	0′ COS	ANGLE

ANGLE	TAN 0′	12′	24′	36′	48′	60′	
0	.0000	.0035	.0070	.0105	.0140	.0175	89
1	.0175	.0209	.0244	.0279	.0314	.0349	88
2	.0349	.0384	.0419	.0454	.0489	.0524	87
3	.0524	.0559	.0594	.0629	.0664	.0699	86
4	.0699	.0734	.0769	.0805	.0840	.0875	85
5	.0875	.0910	.0945	.0981	.1016	.1051	84
6	.1051	.1086	.1122	.1157	.1192	.1228	83
7	.1228	.1263	.1299	.1334	.1370	.1405	82
8	.1405	.1441	.1477	.1512	.1548	.1584	81
9	.1584	.1620	.1655	.1691	.1727	.1763	80
10	.1763	.1799	.1835	.1871	.1908	.1944	79
11	.1944	.1980	.2016	.2053	.2089	.2126	78
12	.2126	.2162	.2199	.2235	.2272	.2309	77
13	.2309	.2345	.2382	.2419	.2456	.2493	76
14	.2493	.2530	.2568	.2605	.2642	.2679	75
15	.2679	.2717	.2754	.2792	.2830	.2867	74
16	.2867	.2905	.2943	.2981	.3019	.3057	73
17	.3057	.3096	.3134	.3172	.3211	.3249	72
18	.3249	.3288	.3327	.3365	.3404	.3443	71
19	.3443	.3482	.3522	.3561	.3600	.3640	70
20	.3640	.3679	.3719	.3759	.3799	.3839	69
21	.3839	.3879	.3919	.3959	.4000	.4040	68
22	.4040	.4081	.4122	.4163	.4204	.4245	67
23	.4245	.4286	.4327	.4369	.4411	.4452	66
24	.4452	.4494	.4536	.4578	.4621	.4663	65
25	.4663	.4706	.4748	.4791	.4834	.4877	64
26	.4877	.4921	.4964	.5008	.5051	.5095	63
27	.5095	.5139	.5184	.5228	.5272	.5317	62
28	.5317	.5362	.5407	.5452	.5498	.5543	61
29	.5543	.5589	.5635	.5681	.5727	.5774	60
30	.5774	.5820	.5867	.5914	.5961	.6009	59
31	.6009	.6056	.6104	.6152	.6200	.6249	58
32	.6249	.6297	.6346	.6395	.6445	.6494	57
33	.6494	.6544	.6594	.6644	.6694	.6745	56
34	.6745	.6796	.6847	.6899	.6950	.7002	55
35	.7002	.7054	.7107	.7159	.7212	.7265	54
36	.7265	.7319	.7373	.7427	.7481	.7536	53
37	.7536	.7590	.7646	.7701	.7757	.7813	52
38	.7813	.7869	.7926	.7983	.8040	.8098	51
39	.8098	.8156	.8214	.8273	.8332	.8391	50
40	.8391	.8451	.8511	.8571	.8632	.8693	49
41	.8693	.8754	.8816	.8878	.8941	.9004	48
42	.9004	.9067	.9131	.9195	.9260	.9325	47
43	.9325	.9391	.9457	.9523	.9590	.9657	46
44	.9657	.9725	.9793	.9861	.9930	1.000	45
45	1.000	1.007	1.014	1.021	1.028	1.035	44
	60′	48′	36′	24′	12′	0′ COT	ANGLE

ANGLE	TAN 0′	12′	24′	36′	48′	60′	
46	1.036	1.043	1.050	1.058	1.065	1.072	43
47	1.072	1.080	1.088	1.095	1.103	1.111	42
48	1.111	1.118	1.126	1.134	1.142	1.150	41
49	1.150	1.159	1.167	1.175	1.183	1.192	40
50	1.192	1.200	1.209	1.217	1.226	1.235	39
51	1.235	1.244	1.253	1.262	1.271	1.280	38
52	1.280	1.289	1.299	1.308	1.318	1.327	37
53	1.327	1.337	1.347	1.356	1.366	1.376	36
54	1.376	1.387	1.397	1.407	1.418	1.428	35
55	1.428	1.439	1.450	1.461	1.472	1.483	34
56	1.483	1.494	1.505	1.517	1.528	1.540	33
57	1.540	1.552	1.564	1.576	1.588	1.600	32
58	1.600	1.613	1.626	1.638	1.651	1.664	31
59	1.664	1.678	1.691	1.705	1.718	1.732	30
60	1.732	1.746	1.760	1.775	1.789	1.804	29
61	1.804	1.819	1.834	1.850	1.865	1.881	28
62	1.881	1.897	1.913	1.929	1.946	1.963	27
63	1.963	1.980	1.997	2.015	2.032	2.050	26
64	2.050	2.069	2.087	2.106	2.125	2.145	25
65	2.145	2.164	2.184	2.205	2.225	2.246	24
66	2.246	2.267	2.289	2.311	2.333	2.356	23
67	2.356	2.379	2.402	2.426	2.450	2.475	22
68	2.475	2.500	2.526	2.552	2.578	2.605	21
69	2.605	2.633	2.661	2.689	2.718	2.748	20
70	2.748	2.778	2.808	2.840	2.872	2.904	19
71	2.904	2.938	2.971	3.006	3.042	3.078	18
72	3.078	3.115	3.152	3.191	3.231	3.271	17
73	3.271	3.312	3.354	3.398	3.442	3.487	16
74	3.487	3.534	3.582	3.631	3.681	3.732	15
75	3.732	3.785	3.839	3.895	3.952	4.011	14
76	4.011	4.071	4.134	4.198	4.264	4.332	13
77	4.332	4.402	4.474	4.548	4.625	4.705	12
78	4.705	4.787	4.872	4.959	5.050	5.145	11
79	5.145	5.242	5.344	5.449	5.558	5.671	10
80	5.671	5.789	5.912	6.041	6.174	6.314	9
81	6.314	6.460	6.612	6.772	6.940	7.115	8
82	7.115	7.300	7.495	7.700	7.916	8.144	7
83	8.144	8.386	8.643	8.915	9.205	9.514	6
84	9.514	9.845	10.20	10.58	10.99	11.43	5
85	11.43	11.91	12.43	13.00	13.62	14.30	4
86	14.30	15.06	15.89	16.83	17.89	19.08	3
87	19.08	20.45	22.02	23.86	26.03	28.64	2
88	28.64	31.82	35.80	40.92	47.74	57.29	1
89	57.29	71.62	95.49	143.2	286.5		0
90							
	60′	48′	36′	24′	12′	0′ COT	ANGLE

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Catalog No. 592

FOUR-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
	0	1	2	3	4	5	6	7	8	9

N	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
	0	1	2	3	4	5	6	7	8	9

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Catalog No. 592

ENERGY - TIME RELATIONSHIPS IN MACROSYSTEMS

Interactions in Static Equilibrium Systems

EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT ONE POINT

INTRODUCTION:

In the analysis of vector systems it is frequently necessary to work with equilibrants. An equilibrant is defined as a single vector which, when added to a vector system, makes the vector sum zero. The magnitude of an equilibrant is always equal to the magnitude of the resultant. However, the direction of the equilibrant always differs from the direction of the resultant by 180°.

When a system is in equilibrium the summation of the x and y components is zero. This fact is the basis for calculating the magnitude and direction of equilibrants when using trigonometry. All known vectors are first resolved into their x and y components and then added algebraically. The x and y components of the equilibrant are then easily found since they must have the precise value required to make the summation of the x and y components zero. The direction of the equilibrant is found in the usual manner by using the tangent function.

When the vectors involved in a system which is in equilibrium are drawn graphically, the "start" point and the "end" point of the graph will always be the same point. This fact is the basis for determining the magnitude and direction of equilibrants graphically.

The concept of equilibrium is one of the most fundamental ideas in all of science. Every system, everything which takes up space and has weight, is either in a state of equilibrium or not. What a material does or does not do, what it can or cannot do, is pretty much related to the ability of the substance to change or maintain equilibrium. It is a natural tendency for all matter to move toward a state of equilibrium, a uniform distribution of both matter and energy, in accordance with the concept of entropy.

During the remainder of this year we will be concerned with mechanisms of both static and dynamic equilibrium systems. The Science IV program dwells in particular with the problems that living organisms face in maintaining equilibrium systems essential to life.

Since all matter continuously experiences change it becomes necessary to assume certain boundaries when dealing with a specific equilibrium mechanism in a particular piece of matter. Everything within the boundaries established is referred to as a "closed system". An "equilibrium system", then, has established boundaries and as such may be either a static or a dynamic equilibrium system. One example of a static equilibrium system would be a macro-body at rest in response to two or more forces.

STATIC EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT ONE POINT

I. Characteristics of Static Equilibrium Systems

  A. Isolated Systems

  B. Summation of Vector Quantities

    1. by trigonometry

    2. by graphic techniques

  C. Motion

II. Forces Common in Static Equilibrium Systems

  A. Component Forces

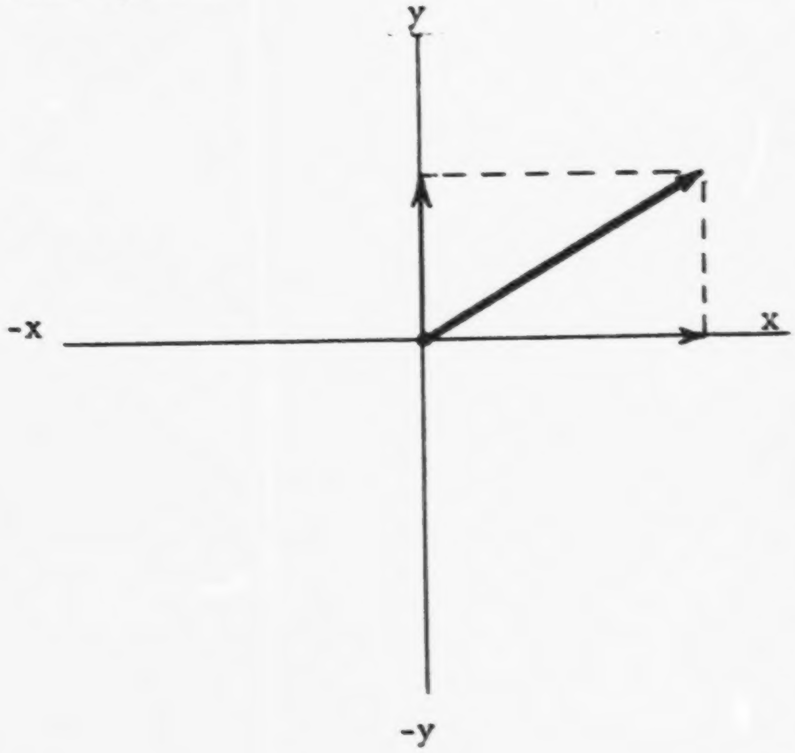
  B. Resultant Forces

  C. Equilibrant Force

  D. Weight Force

  E. Friction Force

  F. Normal Force



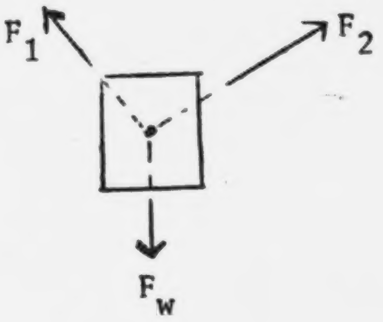
STATIC EQUILBRIUM SYSTEMS

Assume that an object which has a weight of 400 g is subjected to two additional forces, all acting at a common point.

F_1 = 200 g at 130°

F_2 = 450 g at 30°

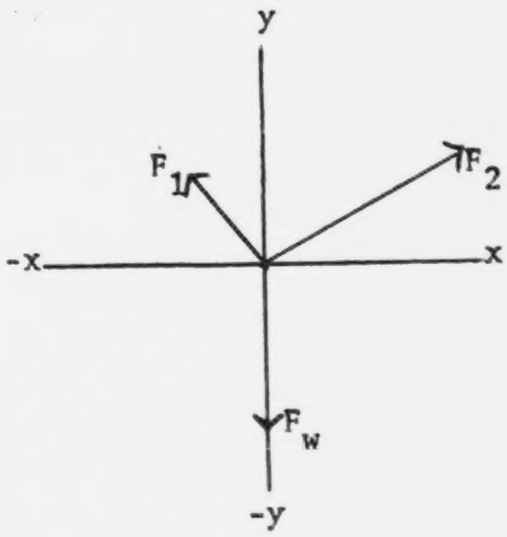
Is this system in equilibrium? If it is not, determine the equilibrant for the system.



I. Trigonometric Solution

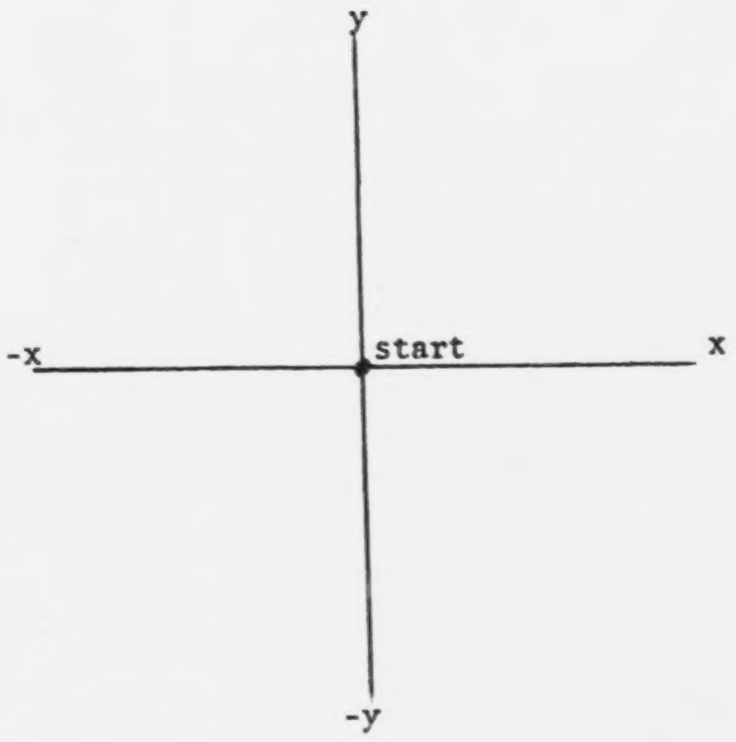
	x	y
F_w		
F_1		
F_2		
*	0	0

*If the system is in equilibrium the summation of the x and y components must = 0.



II. Polygon Solution:

Scale :



Problem Exercise

Name ____________________

Science IIIA **Hour** ______

Date Due ________________

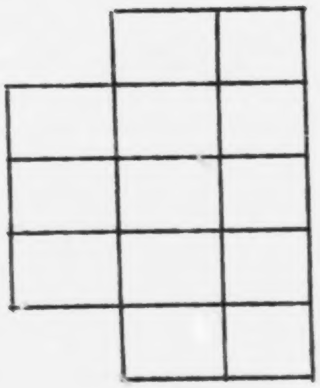
STATIC EQUILIBRIUM SYSTEMS

1. Three forces act upon a single point,

   F_w = 2.2 lb, 270°
   F_1 = 1.6 lb, 160°
   F_2 = 3.2 lb, 60°

   Use trigonometry to calculate the equilibrant force.

   Eq.F. = ____________________

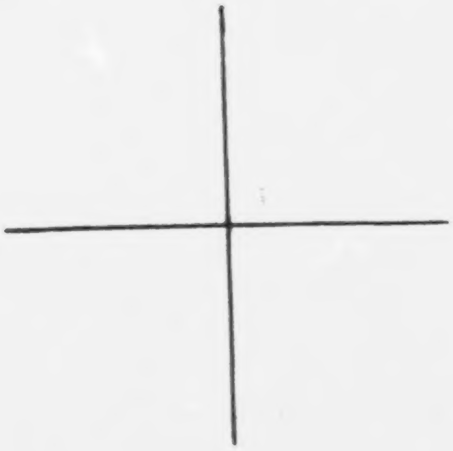


2. An object weighing 40 g is acted upon by three forces,

   F_1 = 20 g at 35°
   F_2 = 80 g at 100°
   F_3 = 60 g at 60°

   Determine the equilibrant graphically.

   Eq.F. = ____________________

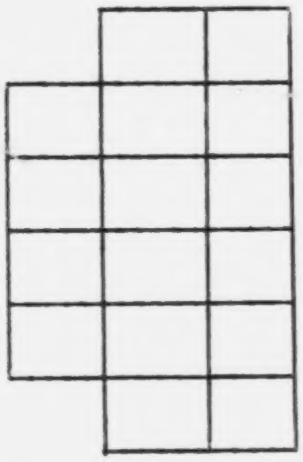


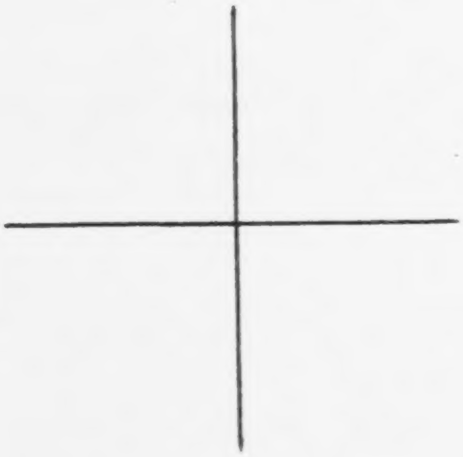
5

3. An object weighing 12 pounds is held in equilibrium by a force (F_1) of 16 pounds acting at 60°, a second force (F_2) acting at an angle of 120°, and a third force (F_3) of 20 pounds. *

Calculate the magnitude of F_2 = __________

the direction of F_3 = __________





*You may use either method.

Laboratory Investigation

THE FORCE OF FRICTION IN EQUILIBRIUM SYSTEMS

If a body is at rest the vector sum of all the forces acting upon it must equal zero. Any body at rest is said to be in equilibrium.

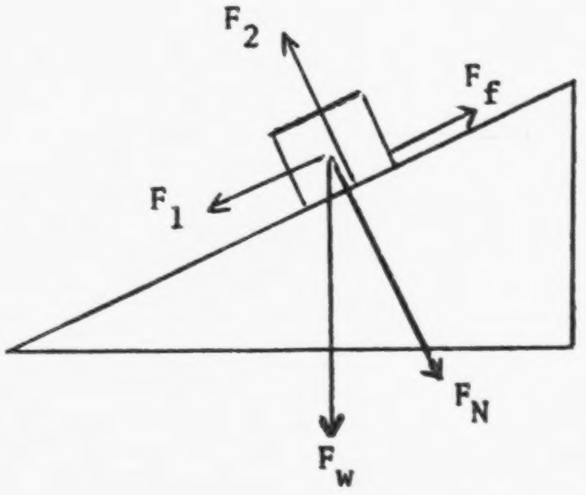
If a body, in motion, from one point in space to another, travels in a straight line and with constant speed the vector sum of all the forces acting upon it must equal zero. A body in motion, under these conditions, is also in equilibrium.

The moment that any body begins to move from one point in space to another it experiences forces which oppose its motion. One such force, which can never be completely eliminated, is the force resulting from the interaction between the molecules on the surface of the moving body and the molecules of the substance through; or over; which the body is moving. Forces such as these always act in a direction which opposes the motion of the body. They are called FRICTION FORCES.

In the system shown below the object placed on the inclined plane is acted upon by four forces.

If the component of the weight force directed down the incline (F_1) does not exceed the friction force the vector sum of the four forces will be zero and the object will be in equilibrium, at rest.

The vector F_N is force acting upon the inclined plane, not the object. It is equal in magnitude but opposite in direction to the force F_2 which is the force exerted upon the object by the inclined plane.



If the object shown were moved up the incline, with constant speed, the ff would oppose the motion upward and the force required to produce the uniform motion up the incline would have to be equal to the sum of F_1 and ff directed down the incline.

In order to learn more about the nature of friction forces and about the equilibrium of forces on a body in motion you are to devise a series of experiments which will enable you to collect data which may be used to illustrate how:

(1) Friction forces are affected by the area of contact between sliding surfaces.

(2) Friction forces are related to the angular displacement of the sliding surfaces.

(3) The friction force is related to the gravitational component of the weight force of the sliding object, perpendicular to the sliding surface, at various angles.

(4) A mathematical relationship between forces may be used to predict the magnitude of a friction force between any two surfaces, at any angle.

The Presentation of Data portion of your report should include a diagram showing the direction and magnitude of all the forces acting in the system and a graph showing the relationship between friction force and normal force.

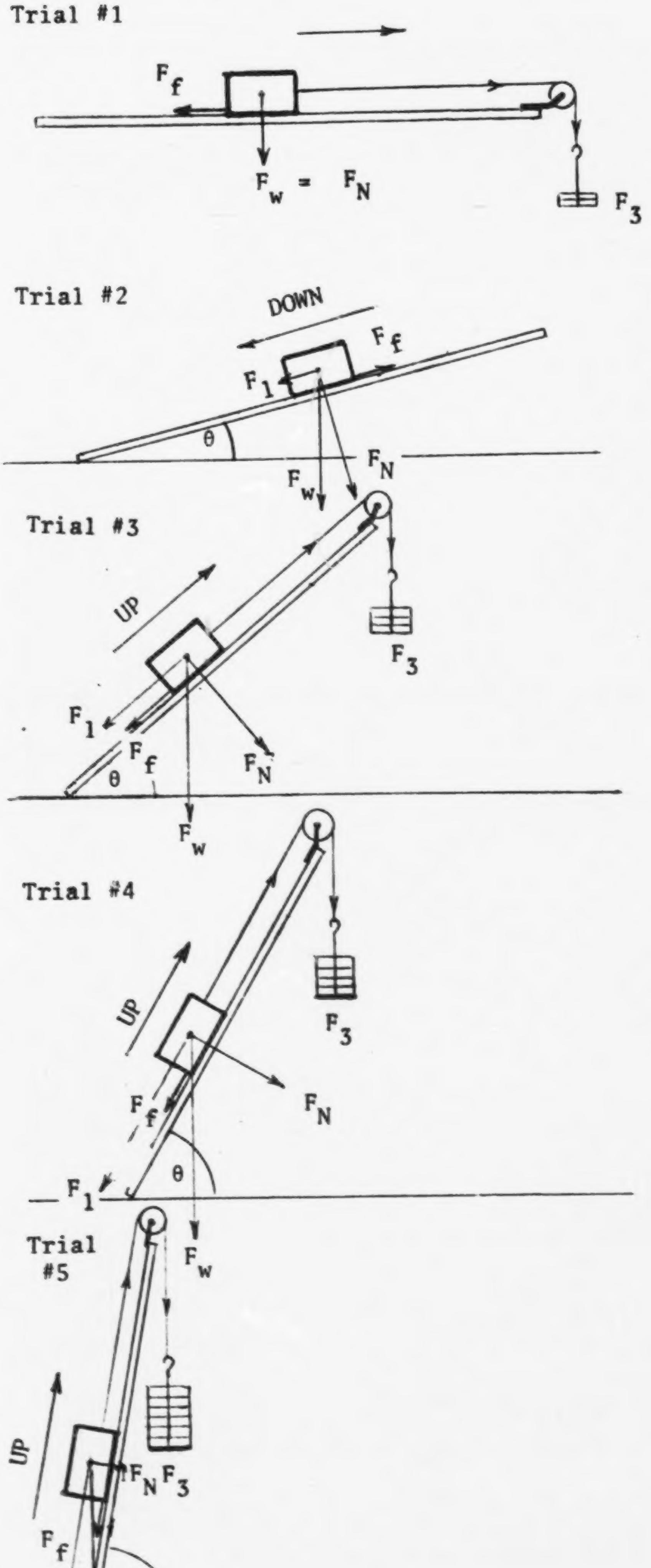
The Conclusion should contain four statements which answer the four questions above.

Name ____________________

Science IIIA Hour ____ 7

Date ____________________

STUDY OF FRICTION FORCES


Trial #1
F_f
$F_w = F_N$
F_3
Trial #2
DOWN
F_f
F_1
θ
F_w
F_N
Trial #3
UP
F_3
F_1
F_f
F_N
θ
F_w
Trial #4
UP
F_3
F_f
F_N
θ
F_1
F_w
Trial #5
UP
F_N
F_3
F_f
θ
F_1
F_w

Trial #	h	l	θ	sin θ	cos θ	F_w	F_N	F_1	F_3	ff	"K"
1											
2											
3											
4											
5											

Interactions in Static Equilibrium Systems

Resource Material

EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT MORE THAN ONE POINT

Required Reading:	Modern Physics, pages 51-59
Recommended Reading:	"Moments, Torques, or Twists", Mechanics, Alexander Efron, pages 20-35

QUESTIONS FOR CONSIDERATION:

1. Discuss the condition required to produce equilibrium in a system involving forces acting at more than one point.

2. What is the relationship between distance and force that is required in the definition of torque? How is this distance determined in systems where the forces acting are not parallel?

3. What is the difference between torque or "moment" and work? Under what conditions will a system experience torque?

4. What is meant by the term "couple" as it applies to the concept of torque? What does the torque of a couple depend upon?

5. In actual practice all torque systems are composed of material substances which have weight. The weight force is always considered to be a vector at 270°. How is the weight of a torque system taken into account when determining the conditions for equilibrium?

6. All torque systems involve "translational motion" and "rotational motion". No torque system is in equilibrium until both of these types of motion is zero.
    a. Discuss the condition required to produce translational and rotational equilibrium.
    b. In solving a torque problem involving couples which type of motion is handled first, or doesn't it make any difference?

INTRODUCTION:

In the vast majority of natural systems involving the interaction of forces, the forces do not act at a single point. When this is the case two types of motion are possible, translational (linear) motion, in the direction of the resultant force, and also rotational motion. In order to produce or maintain equilibrium in a system of this type it is necessary that the resultant force in the system have the proper magnitude and direction to prevent both translatory and rotational motion.

EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT MORE THAN ONE POINT

(Parallel Forces)

I. Motion Resulting from Forces Acting at More Than One Point

  A. Translational Motion

  B. Rotational Motion

    1. Torque

    2. Center of Moments and Choice of Location

II. Conditions Required for Equilibrium

  A. Summation of Forces

  B. Summation of Torques

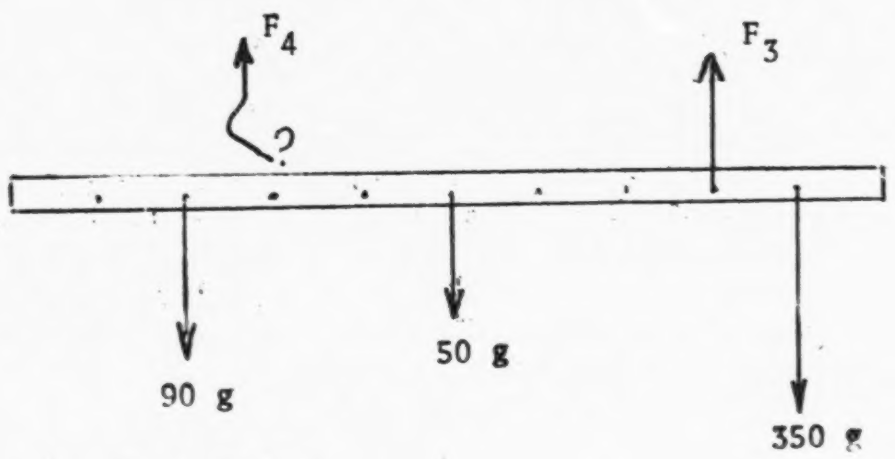
III. Methods of Determining Condition for Equilibrium

  A. Trigonometric

  B. Graphic

Name ____________________
Science IIIA Hour ___
Date Due ________________

Calculate the magnitude of F_3 and the magnitude and position of F_4 required to produce equilibrium.



Scale: 1 cm. = 10 cm.

1. Translational Equilibrium

2. Rotational Equilibrium

Problem Exercise

Name ________________

Science IIIA Hour ____

Date Due ____________

EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT MORE THAN ONE POINT

(Parallel Forces)

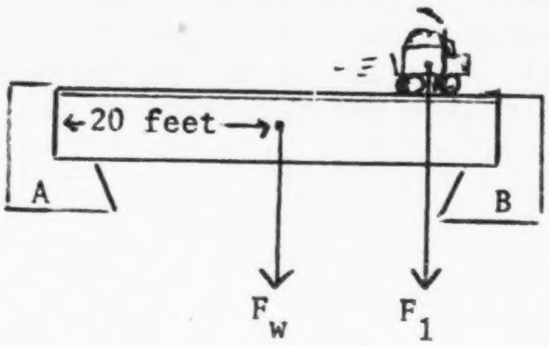
1. A wooden telephone pole, 25 feet long, has its center of gravity 8 feet from the heavy end. The pole weighs 400 pounds. What force would a man have to exert to support the heavy end? the light end?

2. A meter stick, weighing 180 grams is held in equilibrium by strings attached at the 20 and 90 centimeter marks. A weight of 800 grams is hung at the 10 centimeter mark, 40 grams at 30 centimeters, and 300 grams at 70 centimeters. Calculate the magnitude of the force in each string.

13

3. A meter stick of uniform density, weighing 200 grams is subjected to a downward force of 60 grams at the 80 centimeter mark, an upward force of 30 grams at 40 centimeters, and a downward force of 120 grams at 10 centimeters. Calculate the magnitude, direction, and position of the equilibrant force.

4. The bridge span in the diagram is 40 feet long and weighs 12 tons. Calculate the force exerted by the bridge abutments A and B when a truck weighing 10 tons is 8 feet from B.



EQUILIBRIUM IN SYSTEMS WITH FORCES ACTING AT MORE THAN ONE POINT

(Non-Parallel Forces)

INTRODUCTION:

As one might suspect, the forces acting upon a body at more than one point do not have to be parallel to each other. As a matter of fact, most frequently they are not. The question now arises, how does one calculate equilibrants in a couple where the forces are not parallel. The answer is, by the same basic procedures one uses in working with systems involving parallel forces: (1) establish translatory equilibrium by summation of forces, and (2) establish rotational equilibrium by summation of torques.

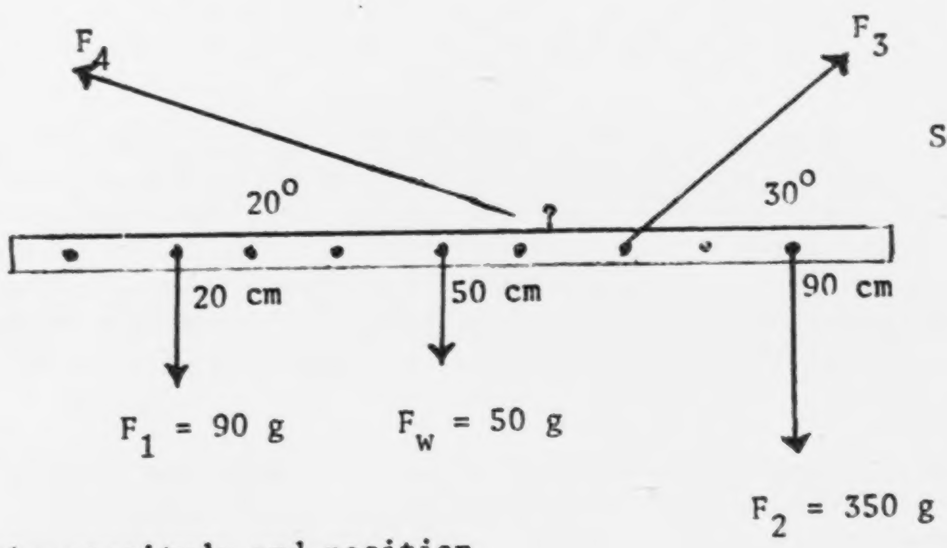
The outstanding difference is associated with the determination of the values for "d" in the definition for torque, $T = F \cdot d$ $(F \perp d)$. The perpendicular distance "d" is the distance from the center of moments, perpendicular to the force or the force extended. The values for "d" may be determined graphically or by using trigonometry.

I. Conditions for Equilibrium of Non-Parallel Forces Acting at More Than One Point

   A. Translational Equilibrium

   B. Rotational Equilibrium

II. Calculation of Equilibrants

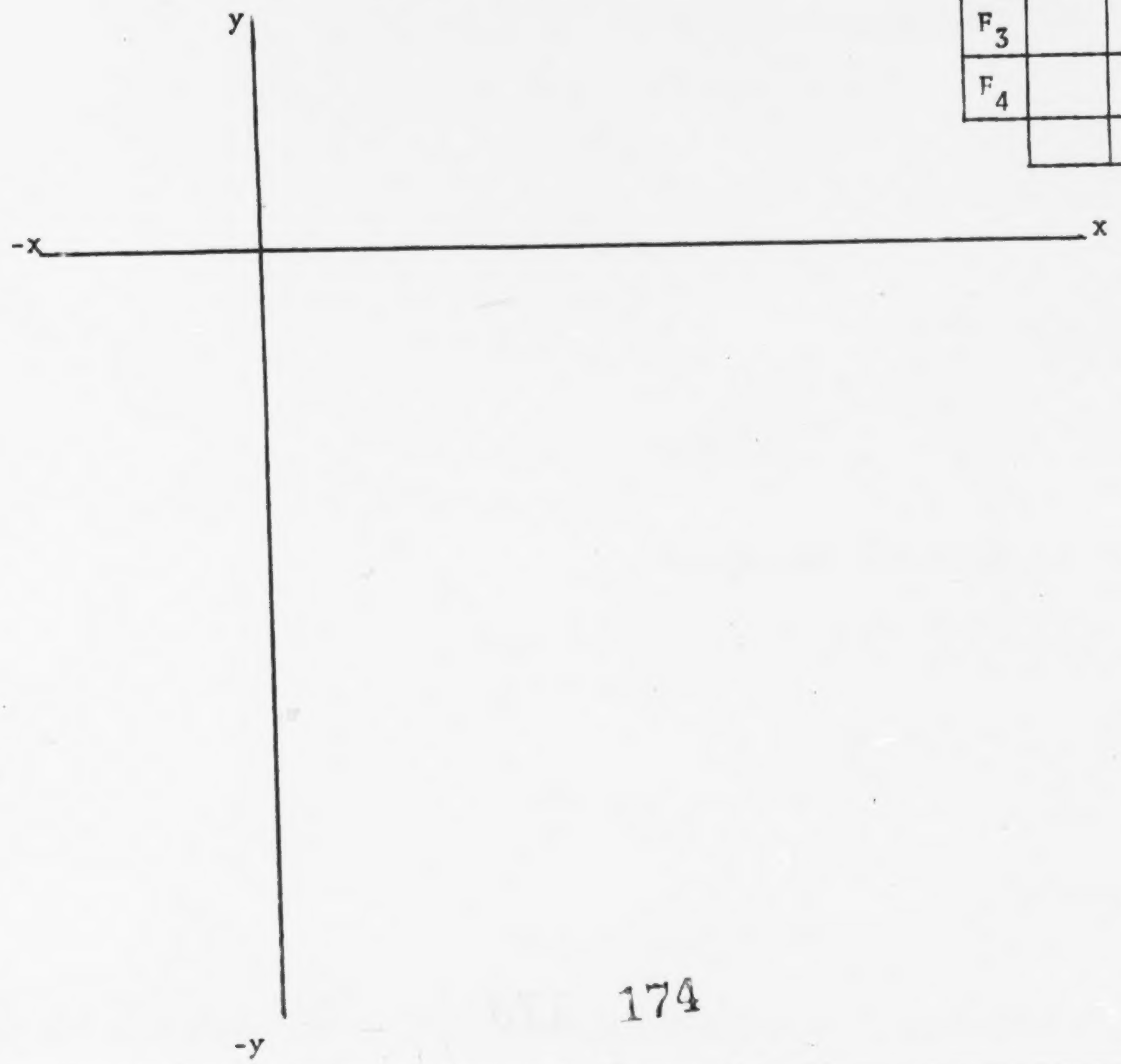

F_4
F_3
20^o
30^o
?
20 cm
50 cm
90 cm
F_1 = 90 g
F_w = 50 g
F_2 = 350 g

Scale: 1 cm = 10 cm

Calculate the magnitude and position of F_4 and the magnitude of F_3.

	x	y
F_w		
F_1		
F_2		
F_3		
F_4		

A. Translatory Equilibrium



B. Rotational Equilibrium

1. clockwise torques

2. counterclockwise torques

3. summation of torques

RESULTS:

F_3 = __________

F_4 = __________

position = ______

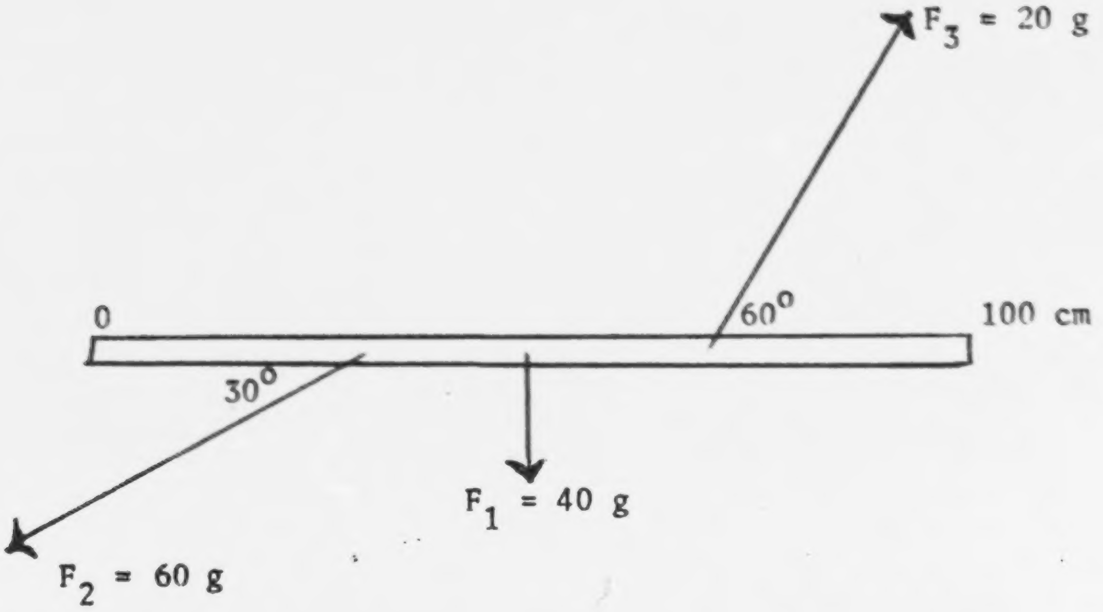
Problem Exercise

Name ____________________
Science IIIA Hour ___
Date Due ________________

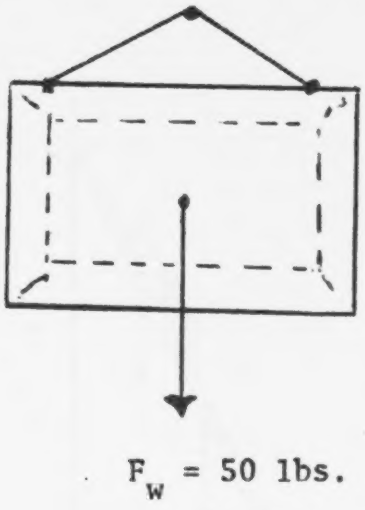
EQUILIBRIUM SYSTEMS WITH FORCES ACTING AT MORE THAN ONE POINT

(Non-Parallel Forces)

1. With reference to the diagram shown, calculate the position, magnitude, and direction of a single force which will produce equilibrium.



2. A picture weighing 50 pounds is hung from a wire which makes an angle of 70° with the vertical. Calculate the tension on the wire.

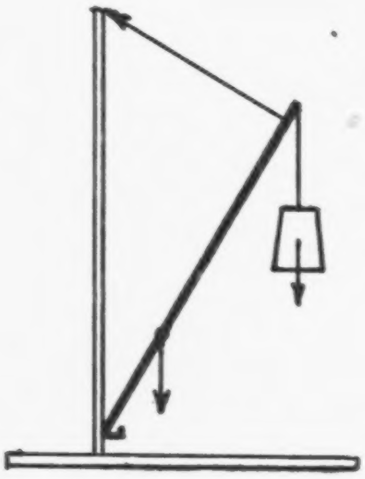


3. The boom of the crane shown is 16 feet long and weighs 180 pounds Its center of gravity is 6 feet from the base end. The boom makes an angle of 60° while supporting F_1 at the 16 foot mark. The angle between the tie cable and the boom is 90°. The tie cable is attached to the boom at the 15 foot mark. Calculate:

   a. the force on the tie cable -

   b. the magnitude and direction of the force exerted by the lower support against the boom -

   Assume the system is in equilibrium.



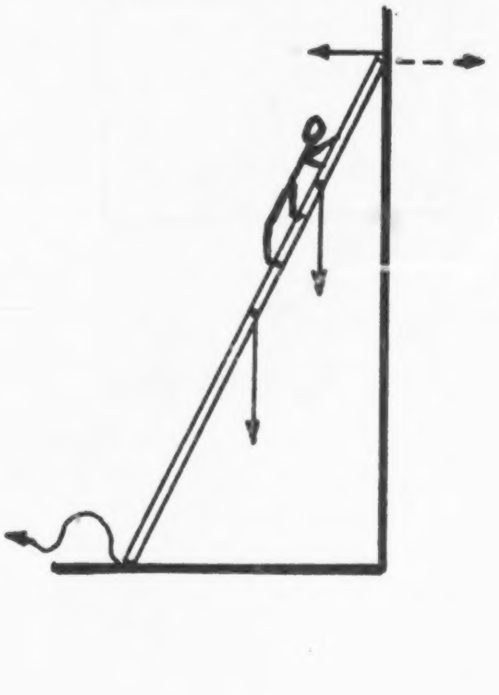
4. A uniform ladder, 16 feet long, leans against a smooth wall at an angle of 60°. The ladder weighs 30 pounds. A man weighing 160 pounds stands on the ladder at a point 12 feet from the bottom end. Calculate the forces exerted on the ladder:

   a. by the wall

      F_2 = ________, 180°

   b. by the ground

      F_3 = ________, ____



INTERACTIONS IN STATIC EQUILIBRIUM SYSTEMS

Equilibrium Systems with Forces Acting at More Than One Point

SOLUTION OF PROBLEMS WITH MINIMUM INFORMATION

I. Information Relative to the Solution of Problems Involving Vector Systems in Equilibrium

A. Maximum

B. Minimum

II. Basis for Solving Problems

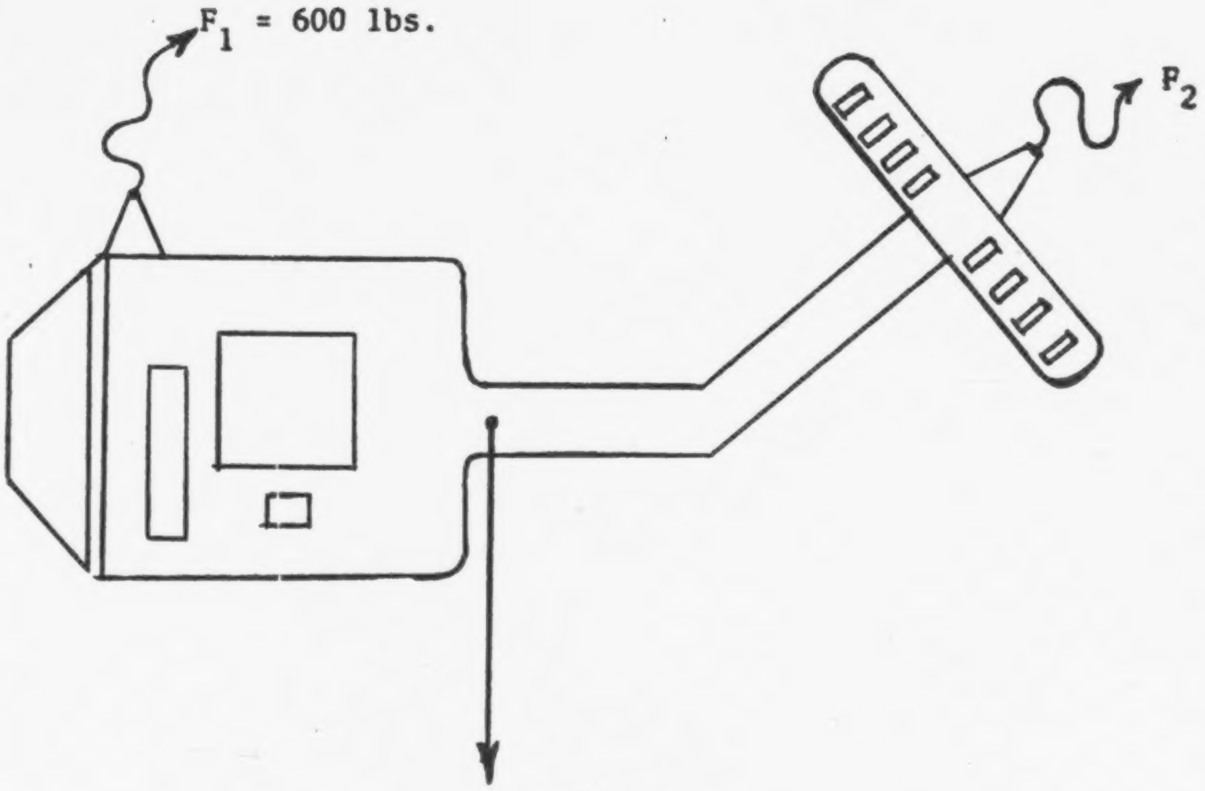
A. Significance of the Torque Definition

B. Significance of Knowing that a System is in Equilibrium

C. Problems with Two Possible Solutions

III. Mechanics of Solving Problems Involving Three Vectors In Equilibrium with Three Unknowns

The system shown below is in equilibrium: Calculate the magnitude and direction of F_2 and the direction of F_1. Give both of the possible solutions.



Problem Exercise

Name ______________________________

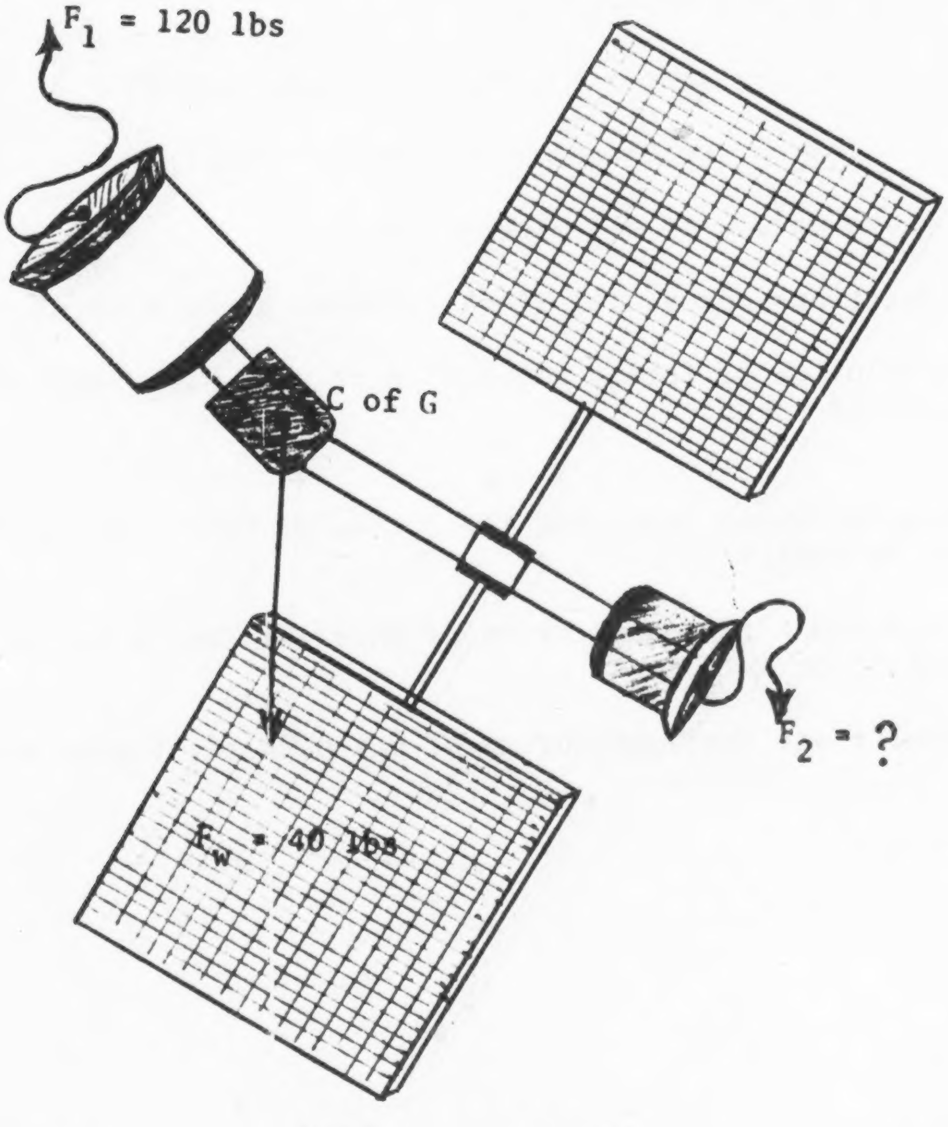
Science IIIA Hour _____

Date ______________________________

EQUILIBRIUM SYSTEMS WITH THREE UNKNOWNS

Find the direction and magnitude of F_2 and the direction of F_1 required to establish equilibrium in the system below.

Give both of the possible solutions.



SUMMARY OF CONCEPTS

INTERACTION OF FORCES IN EQUILIBRIUM SYSTEMS

I. Definitions:

Vector

Scalar

Component Force

Resultant Force

Equilibrant Force

Torque

Force moment

Center of moments

Center of gravity

Friction force

II. Problem Types Involving the Action of Forces Upon a Single Point

Resolution of forces into x and y components

Determination of a resultant force; magnitudes and directions of all component forces known.

(a) by vector addition (Polygon method)

(b) by rectangular resolution (trig)

Determination of equilibrant force

Conditions for equilibrium of forces about a point.

Resolution of forces about a point when both magnitude and direction are not known.

III. Problem Types Involving the Action of Forces at Different Points on an Object

Conditions for equilibrium of parallel forces acting at different points on an object.

Conditions for equilibrium of non parallel forces acting on a body.

INTERACTIONS IN DYNAMIC SYSTEMS

Dynamic Systems in Equilibrium

Dynamic Systems Not In Equilibrium

Resource Material

INTERACTIONS IN DYNAMIC SYSTEMS

Required Reading: *Modern Physics*, Chapter 4, pages 66-89

Recommended Reading:
"Kinematics", Basic Science Series #200-3, Chaps. 3 & 4
"Isaac Newton", I. Bernard Cohen
Lives in Science, Scientific American Book
Mass, Length, and Time, Norman Feather,
    Chap. 8: The Concepts of Force and Mass
    Chap. 10: The Universal Gravitation
Sir Isaac Newton, His Life and Work, E.N. da C Andrade
PSSC Physics,
    Chap. 20: Newton's Laws of Motion
    Chap. 21: Motion at the Earth's Surface
    Chap. 22: Universal Gravitation and the Solar System

Audio Visual Program: "The Cavendish Experiment" by Dr. Melter, Ohio State University

QUESTIONS FOR CONSIDERATION:

1. What is meant by the expression, "dynamic equilibrium"? How is it possible for a body which is moving to be in equilibrium? Describe the conditions under which a body may be considered to be in dynamic equilibrium.
2. Discuss the difference between initial, final, and average velocity.
3. What is acceleration? Under what conditions does a body experience acceleration? Can a body which is being accelerated or decelerated be in equilibrium? Explain.
4. Describe the motion of a body in response to a resultant force not equal to zero. Express these ideas in terms of mathematical relationships.
5. What is mass? How does the mass of a body differ from its weight?
6. Explain why objects which have different weights fall toward the earth at the same rate.
7. What is the bases for establishing force units in the absolute system of measurement? Explain why an object which has a mass of one pound also has a weight of one pound. Does this mean that mass and weight are the same thing? Explain how conversions between gravitational and absolute units are handled.
8. Discuss the difference between impulse and momentum. How do the units for impulse compare to the units for momentum? What is the significance of this relationship of units?
9. Discuss the Newtonian Law of "universal gravitation". What is the purpose and numerical value of the proportionality constant, α, in this equation?
10. **Are there any limitations to Newton's Laws of Motion? If so, discuss them. Which of Newton's Laws of Motion describe the motion of a body when $RF = 0$? When $RF \neq 0$?**

DYNAMIC SYSTEMS IN EQUILIBRIUM

INTRODUCTION:

Up to this point in our study of systems involving the interaction of forces all of our experiences relating the effects of forces on matter have been unique. In every instance, either the sum of the forces and, or, torques acting were part of an existing equilibrium system, or, they have been directed to produce equilibrium within a system. Secondly, we have been concerned only with static equilibrium systems, that is, closed systems at rest.

When the summation of forces and, or, torques acting within a system equal zero, the system is in equilibrium, but it does not have to be at rest. A body in motion with a constant velocity is also in equilibrium. An automobile veling along a straight and level highway at sixty miles per hour is a ystem in equilibrium. The auto will continue to travel in the same direction and with the same speed until forces act to disturb its equilibrium state. When the auto begins to travel up or down an incline along the roadway, gravitational forces change within the system and the auto will either speed up or slow down. When the auto approaches a curve in the roadway a force applied to the steering mechanism disturbs the equilibrium of the system in order to produce the change in direction required to keep the vehicle on the roadway.

It is very important to understand that any system, in equilibrium, may be at rest or in motion with constant speed and direction. To change from the "at rest" state or the motion with "constant velocity state" requires a change in equilibrium resulting from changes in the summation of forces within the system.

Our first investigations of dynamic systems, systems, not at rest, will be concerned with the motion of a body in dynamic equilibrium. In this system the summation of all external torques and forces, exluding friction, will be zero.

Our second investigation will involve a dynamic system not in equilibrium. These investigations will provide information which can be used to make a quantitative analysis of the motions of bodies and the forces that produce them.

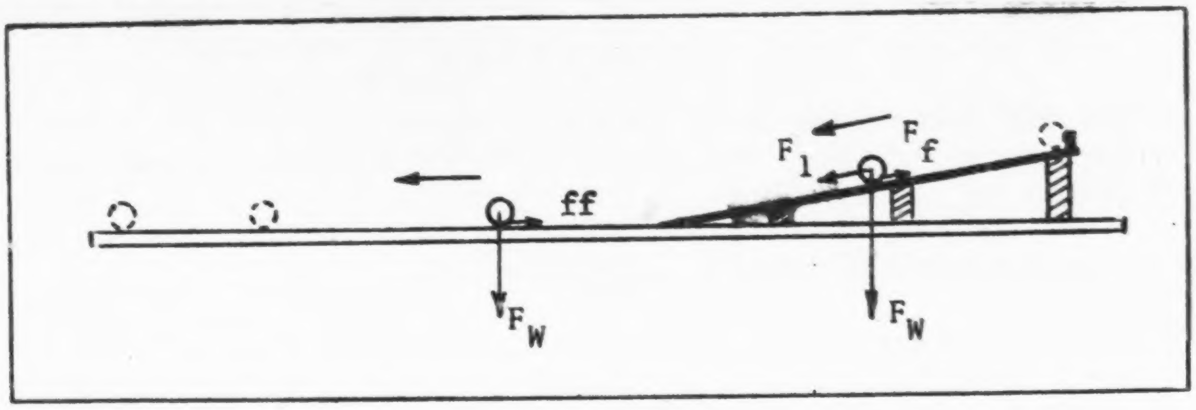
DYNAMIC SYSTEMS IN EQUILIBRIUM

(RF$\neq$0 but constant)

INTRODUCTION:

One convenient method of studying the motion of a body in dynamic equilibrium is to develop a system which utilizes gravitational forces to produce motion. The advantage of such a system is that the gravitation forces between the earth and a relatively small object at a given position on its surface are constant and easily measured.

If a steel ball is placed on an inclined plane and then released, the ball will roll down the incline.



In this system two forces act in a direction parallel to the incline. The force responsible for the motion of the ball down the incline is F_1, the component of the "weight force", F_W, of the ball. The magnitude of this component force, F_1, can be determined graphically or by trigonometry, if the weight of the ball and the angle of the incline are known.
$F_1 = \sin\theta \cdot F_W$
The second force acting parallel to the incline is the friction force F_f
Friction force is defined as a force which opposes the motion of a body in any medium. Whenever a body moves it experiences friction forces which oppose the motion. Friction forces can be reduced by a number of processes but they can never be eliminated. $F_f = \mu \cdot F_N$

The steel ball will roll down the incline if the component of the weight force, F_1, parallel to the incline is greater than the friction force. Since the friction force is very small, especially for a rolling body, it does not require a very steep incline to produce a component force sufficiently large to move the ball.

After the ball travels the entire length of the incline and reaches the horizontal surface, the component of the weight force parallel to the direction of the motion of the ball becomes zero. Now the only force opposing the motion of the ball is F_f. If this F_f could be eliminated, the ball would represent a body in dynamic equilibrium and it would continue to move over the horizontal surface with constant speed and direction.

Actually the F_f is so small that the motion of the ball, during the first second or two of its travel along the horizontal surface, very nearly exhibits the characteristics of a dynamic system, in equilibrium. At least the similarity is close enough to assume, for our purposes, that it is a dynamic system in equilibrium.

Let us assume that the ball was placed at the upper end of the incline and held there, at rest, by applying a restaining force. The instant that this force is removed the RF acting on the ball is no longer zero, but, the velocity of the ball, at that instant, is zero. The velocity of a body at the beginning of a period of observation is called the "initial velocity" and has the symbol u. Shortly after the restraining force has been removed, the ball, in response to the RF ≠ zero, is traveling down the incline with an increasing rate of speed. By the time the ball reaches the horizontal surface, where the RF parallel to the direction of travel is zero, the ball will have acquired its maximum velocity. The velocity at the end of this time interval is called the "final velocity" and it has the symbol v.

Now, if there were no F_f acting to oppose the motion of the ball along the horizontal surface, the distance that the ball traveled during the first second of its motion along the horizontal surface would be the same as the final velocity acquired by the ball while rolling down the incline. (Recall that velocity is the distance/time.)

In this investigation we shall be interested in measuring the final velocity of a steel ball during the first second of its motion along a horizontal surface. That is, we will be measuring the velocity of the ball while it is in "dynamic equilibrium".

PROBLEM: The purpose of this investigation is to obtain experimental data which will enable us to quantitatively describe the motion of a body which is in dynamic equilibrium - that is, the motion of a body in response to a RF which is constant but not zero.

PROCEDURE: Set up an inclined plane at the particular angle required to permit the steel ball, starting from rest, to traverse its entire length in precisely 6.0 seconds. Make certain that the RF acting on the ball is constant over the entire length of the incline. This means that there can be no "dips" or "rises" along the track. It must remain straight under the weight of the ball.

Measure the distance the ball traveled down the incline (RF ≠ 0) during the 6 second interval and also the distance traveled along the horizontal surface (RF now = 0) during the next second.

Start the ball, in successive trials, at precisely that location on the incline which will enable the ball, starting from rest, to travel the remaining distance down the incline in exactly 5, 4, 3, 2, and 1 second(s). *(DO NOT alter the angle of the incline during these trials! Any change in the angle would change the magnitude of the RF acting upon the ball, thus introducing a second variable in the experiment.) For each trial measure and record the distance traveled by the ball down the incline and also the distance traveled along the horizontal surface during the next second. Run enough trials for each time interval to obtain experimentally reliable results.

Remember, since the data is obtained by experimental means it will reflect errors in technique and measurement. These errors may become obvious when the data is represented graphically.

After having completed the data table prepare a graph which shows the relationship between the distance the ball travels along the incline as a function of time and final velocity vs time. If the graph suggests that there are discrepencies in the data, recheck the values experimentally and make any necessary corrections in your table of data.

Having determined the relative values for distance, time, final and initial velocity for the ball on the incline try to find various combinations of these physical quantities which represent constants.

Laboratory Problem

Name ____________________

Science IIIA Hour _____

Date ____________________

DYNAMIC SYSTEMS NOT IN EQUILIBRIUM

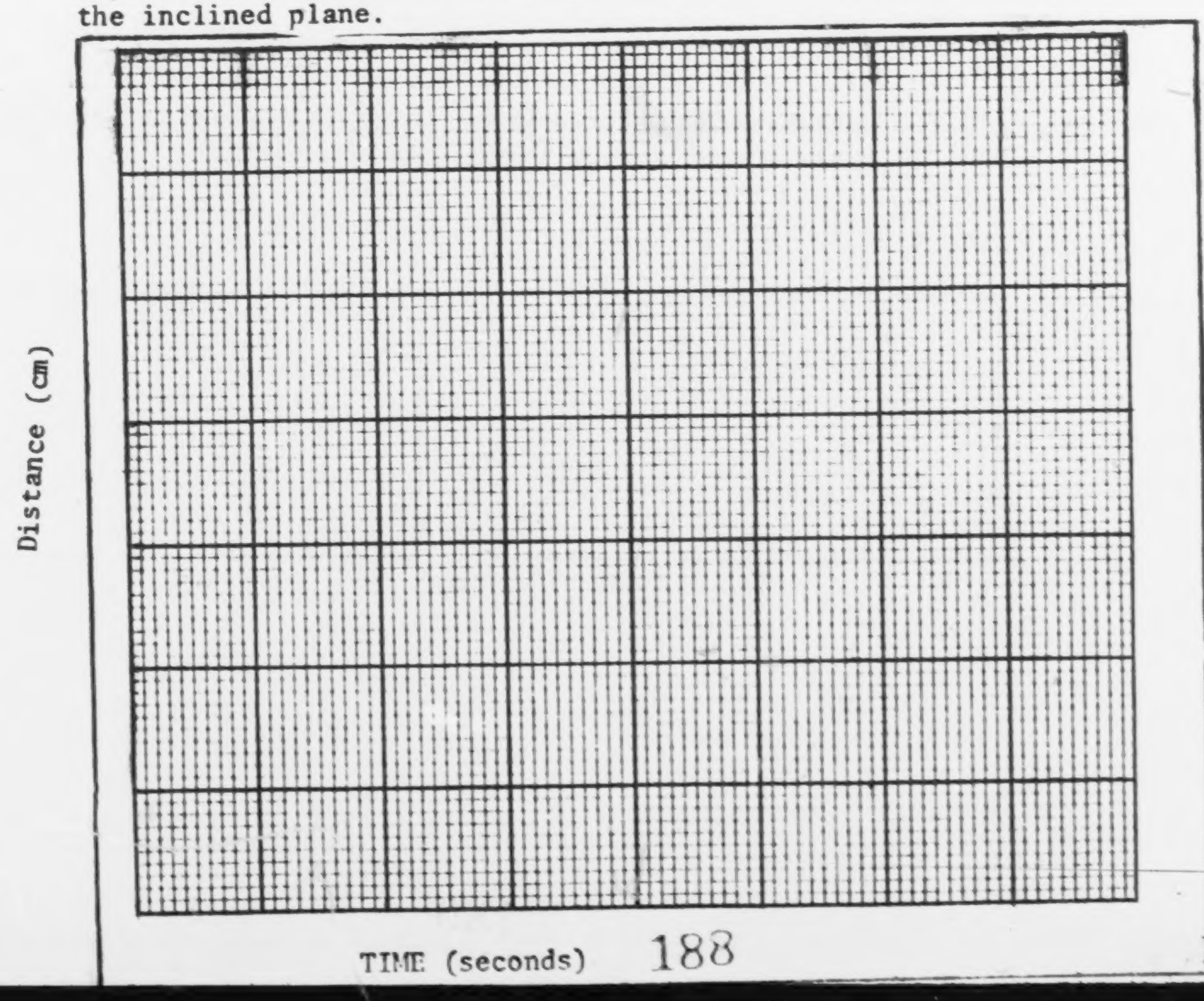
PRESENTATION OF DATA:

MOTION ON HORIZONTAL		
t	s	$\bar{v}$
1		
1		
1		
1		
1		
1		

MOTION DOWN INCLINE			
t_{sec}	s_{cm}	u	v
6		0	
5		0	
4		0	
3		0	
2		0	
1		0	

INTERPRETATION OF DATA			
$\bar{v}$	k=	k=	k=

Represent the distance (d) graphically, as a function of time on the inclined plane.



QUESTIONS:

1. How does the curve for the final velocity vs time relationship compare to the one representing the distance vs time down the incline?

2. What mathematical relationship describes the average velocity ($\bar{v}$) of the ball while traveling down the incline?

3. How does the average velocity ($\bar{v}$) of the ball down the incline compare to its final velocity? Express this relationship in mathematical terms involving v, u, s, and t.

4. Identify two mathematical relationships which appear to describe the modern of a body in dynamic equilibrium ($RF \neq 0$ but constant)

Laboratory Problem

Name ______________________

Science IIIA Hour ____

Date ______________________

DYNAMIC SYSTEMS NOT IN EQUILIBRIUM

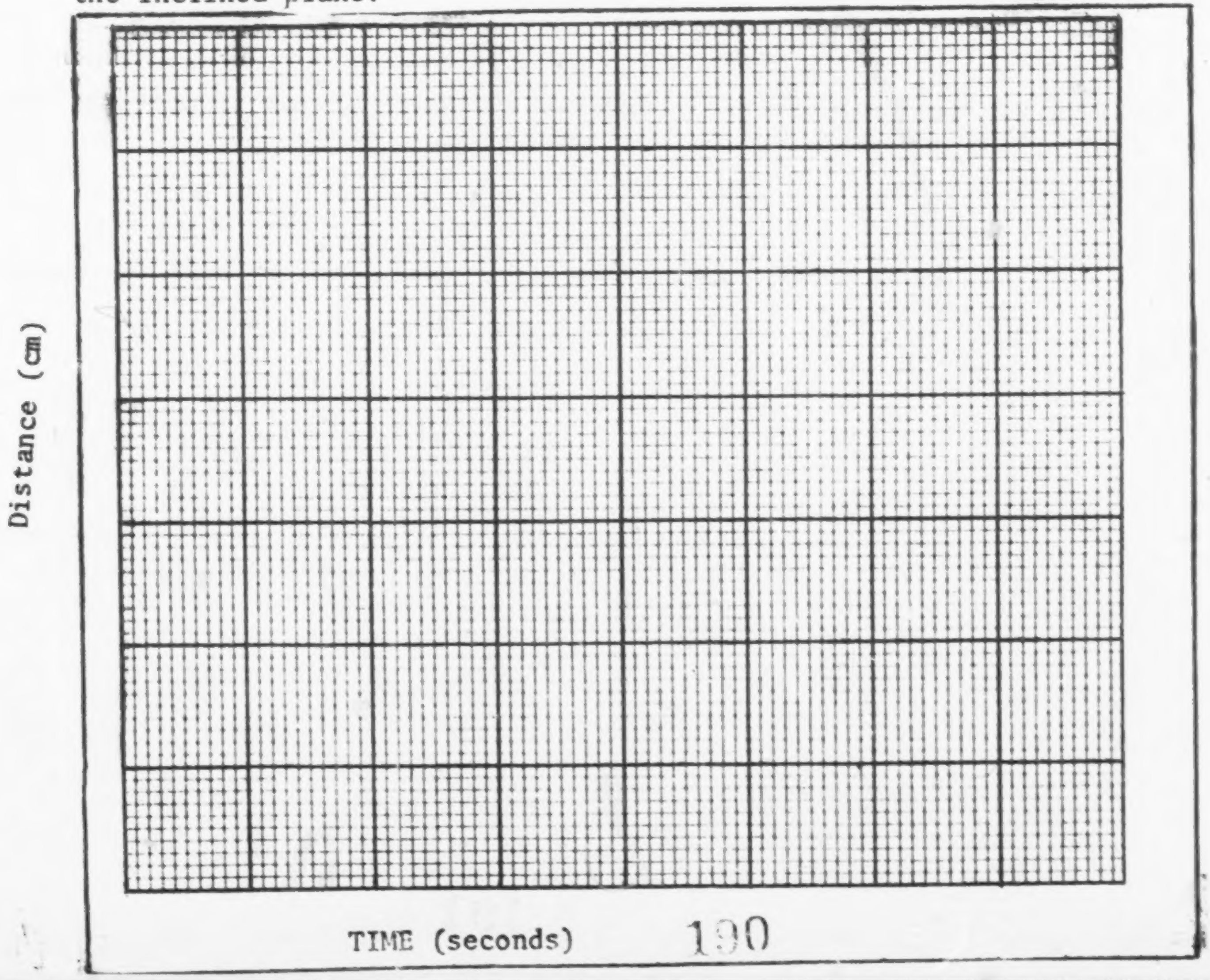
PRESENTATION OF DATA:

MOTION ON HORIZONTAL		
t	s	$\bar{v}$
1		
1		
1		
1		
1		
1		

MOTION DOWN INCLINE			
t_{sec}	s_{cm}	u	v
6		0	
5		0	
4		0	
3		0	
2		0	
1		0	

INTERPRETATION OF DATA			
$\bar{v}$	k=	k=	k=

Represent the distance (d) graphically, as a function of time on the inclined plane.



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INTERACTIONS IN DYNAMIC SYSTEMS

I. Summation of Experimental Investigations

(data taken from average of three students experiments)

weight of ball = 225.8 g
length of incline = 245 cm
height of incline = 3.4 cm for 7 seconds interval

t_{sec}	s_{cm}	$v=\frac{s}{t}$	v	k=	k=	k=

II. Basic Equations Describing Natural Laws with Respect to the Motion of Bodies in Dynamic Systems

III. Derived Equations, Useful in General Problem Solving with Respect to the Motion of Bodies in Dynamic Systems

Problem Assignment

Name ______________________________

Science IIIA Hour _____

Date ________________________

INTERACTIONS IN DYNAMIC SYSTEMS

1. A ball rolling down an incline is observed to have a velocity of 48 cm/sec. Eight seconds later its velocity is 164 cm/sec. Determine:
   a. the acceleration
   b. the average velocity
   c. the distance the ball traveled in the eight second interval

2. A train traveling with a velocity of 90 mi/hr is subjected to a negative acceleration of 4 ft/sec^2. How long will it be before the train is slowed down to a velocity of 15 mi/hr, and how far will it travel during this time?

3. An airplane starting from rest at the beginning of the runway maintains constant acceleration while on the ground. If the plane travels 12 feet in the first two seconds find:
   a. its acceleration
   b. the velocity after 16 seconds
   c. the distance required to attain a velocity of 70 mi/hr

4. A car traveling 60 mi/hr passes a police car traveling at the legal speed of 20 mi/hr. If the police car starts increasing its speed with an acceleration of 4 ft/sec^2, how long will it take the police car to overtake the other car? (Assume the first car maintains its initial velocity) How fast will the police car be going when it reaches the first car?

5. The height of the Empire State Building is 1250 feet. If a ball is thrown directly downward from this height with an initial velocity of 6 feet per second, how far will it travel in the first 8 seconds? How far will it fall during the 7th second? What time is required for the ball to reach the ground? (Assume that the acceleration due to the action of the gravitational force of the earth is equal to 32 ft/sec^2.)

6. A ball is thrown vertically upward with a velocity of 80 feet per second. Calculate the height to which it will rise and the length of time that the ball will be in the air.

7. A baseball was observed to remain in the air for four seconds after leaving the bat and before being caught by the center fielder at a distance of 320 feet from the batter. Calculate the velocity and the direction of the ball at the moment it strikes the fielder's glove. Assume that the ball is caught just above the ground.

8. A balloon at an elevation of 120 feet and traveling vertically upward with a velocity of 30 miles per hour, drops a sand bag. How long does it take the sand bag to reach the earth? With what velocity does it strike the earth?

Extra Credit Problem

Name ____________________

Science IIIA Hour ____

Date ____________________

DYNAMIC SYSTEMS NOT IN EQUILIBRIUM

RF ≠ 0, BUT CONSTANT

An "Able" Rocket was fired vertically from rest position. After reaching an altitude of 120,000 feet its velocity was calculated to be 2000 mi/hr. At this instant the guidance system effected a change in course which made the rocket travel at an angle of 70 degrees above the horizontal axis.

1. Calculate the remaining time for the flight of the rocket.

2. Determine the horizontal distance, from the launching site, covered by the rocket in its flight.

3. Calculate the maximum altitude reached by the rocket.

4. Determine the maximum altitude that the rocket would have attained if it had continued to travel in a vertical direction.

DYNAMIC SYSTEMS NOT IN EQUILIBRIUM

(Variable RF $\neq$ 0, Not Constant)

INTRODUCTION:

We have identified ways of describing the motion of a body when it is made to move by a constant resultant force not equal to zero. It was found that the motion of the body under these conditions resulted in a continuous change in velocity called acceleration. The direction of the velocity and acceleration was the same as the direction of the resultant force producing it.

Suppose that the magnitude of the resultant force acting on a body were changed. What effect would this have on the acceleration? What is the relationship between the magnitude of the resultant force producing motion and the magnitude of the acceleration experienced. In this study we shall attempt to discover that relationship.

One of the most convenient techniques for investigating the relationship between variable resultant forces, not equal to zero, and the acceleration which they produce is to observe the motion of a ball rolling down an inclined plane. By varying the angle of inclination it is possible to maintain variable resultant forces and motions which are relatively simple to measure.

PROBLEM:

How is the magnitude of a resultant force acting on a body related to the acceleration which it produces?

PROCEDURE:

In this experiment we will set up a metal track so that its angle of inclination is about two to three degrees. A steel ball and a pool ball will be started from rest at the end of the incline. The time that each requires to travel the length of the incline will be measured. The resultant force acting on each ball will be calculated.

The gravitational component of the weight force which tends to move the ball down the incline will be very small for small angles of inclination. Therefore, the ff opposing the motion of the ball down the plane will be significant in the summation of the forces acting upon the ball. This ff will be measured and taken into account when determining the RF on the ball.

A. Determine the coefficient of rolling friction for the steel and pool ball.

Your presentation and discussion of data for this portion of the experiment report should be in the form of a vector diagram in which the force vectors are identified. Show equation used, substitutions and final answers.

B. Set up the metal track to give an angle of inclination of about two to three degrees. Determine the time required for the steel ball and the pool ball to travel the entire length of the incline. Make certain that the initial velocity in each trial is zero and that the track maintains a constant slope along its entire length.

After having determined an acceptable experimental average time for the motion of each ball increase the angle of inclination by about two degrees for each of the four more trials.

Laboratory Problem

Name ____________________

Science IIIA Hour ____ 38

Date Due ________________

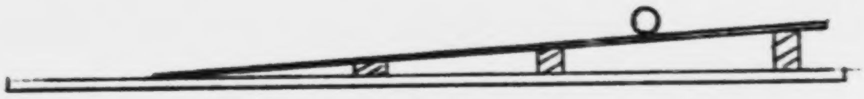
DYNAMIC SYSTEMS NOT IN EQUILIBRIUM

(Variable RF≠0, Not Constant)

PRESENTATION OF DATA:

A. Determination of Friction Forces for Constant Velocity Down the Incline

	Experimental			Calculated Data					
	l	h	F_w	sinθ	θ	F_1	F_f	F_N	$\mu = \frac{F_f}{F_N}$
steel									
pool									



B. Motion of a Body in Response to RF≠0 and not Constant

		Experimental				Calculated Data								
		h	s	F_w	t	sinθ	θ	F_1	F_N	F_f	RF	v	a	k=
steel	μ =													
pool	μ =													

39 C. Show the Graphic Relationship Between the Acceleration and Resultant Forces for Both the Steel and the Pool Ball. Plot RF on the Vertical Axis and Acceleration on the Horizontal Axis. Calculate the Slope of Each Line.

QUESTIONS:

1. Suppose that the resultant force which accelerates the ball is its total weight.

   a. Under what conditions would this be true?

   b. Is there any relation between this weight force acting on the ball and the acceleration which it produces that is similar to the value obtained for the motion of the ball on the inclined plane?

   c. Calculate the quantitative value for this relationship. (Ignore air friction.)

2. What are the units value for the slope of the line graphed in Part C? What is the significance of this slope as a physical quantity?

INTERPRETATION OF DATA:

Name ____________________

INTERACTIONS IN DYNAMIC SYSTEMS

(RF=0, RF≠0 but Constant)

I. Force and Motion

Summary of the natural laws which describe the motion of bodies at rates considerably less than the speed of light.

A. When the RF acting upon a body equals zero.

1. An object at rest, subjected to forces whose resultant equals zero, will remain at rest.
2. An object in motion, under the influence of forces which have a resultant equal to zero, will continue in that state of motion with constant velocity.

These two statements describe what happens to matter when the forces acting upon it do not disturb its motion. This is known as Newton's First Law of Motion.

> A body continues in its state of rest or in uniform motion in a straight line unless it is compelled by some force to change that state.

If the RF on an object equals zero, the acceleration equals zero. If the acceleration equals zero, the velocity does not change.

$$a = \frac{v - u}{t} \qquad v = u + at$$

if $a = 0$, then $v = u + 0t$, that is, $v = u$

(Newton's First Law says: If RF = 0, then a = 0)

B. When the RF does not equal zero.

1. If an object at rest or in a state of uniform motion is subjected to forces whose resultant is not equal to zero, the body will be accelerated. For any given body, moving considerably less than the speed of light:

Natural Laws

$$\bar{v} = \frac{s}{t} = \frac{v + u}{2} ; \qquad a = \frac{v - u}{t}$$

Mathematical Derivations

$$v^2 = u^2 + 2\,as ; \qquad s = ut + \frac{at^2}{2}$$

2. The ratio of the magnitude of the force to that of the acceleration produced is a constant. This constant is given the name mass (m):

$$m = \frac{RF}{a}$$

3. The direction of the acceleration is the same as that of the RF. This is true whether the body is initially at rest or moving in any direction with any velocity.

Since the mass of any object is constnat at speeds considerably less than the speed of light, the acceleration is directly proportional to the RF.

These relationships describe the effect of a RF not equal to zero on a body and the magnitude of the acceleration produced. This relationship is known as Newton's Second Law:

$$RF = ma$$

II. Impulse and Momentum

A. Newton's Third Law states: "for every force acting on one object there is a force, equal in magnitude and opposite in direction, acting on another object".

$F_1 = F_2$, where F_1 is the force on one object and F_2 an equal force on some other object.

B. If we take the equation for acceleration,

$$a = \frac{v - u}{t} ,$$

and solve the equation describing Newton's Second Law, $RF = ma$, for "a" and set them equal to each other we come up with the equation:

$$Ft = mv - mu$$

where Ft equals impulse and mv - mu equals momentum or "stored impulse".

III. Mass vs. Weight

A. Mass - the ratio of the RF on a body to the acceleration produced.

Since this ratio yields the same constant for a given body, regardless of how big or small the RF becomes, we recognize that the mass of a body is constant.

B. Weight - a measure of the gravitational force exerted upon a body by the earth.

For a body falling freely in the earth's gravitational field, the only force acting, neglecting air resistance, is the weight.

The resultant acceleration is called the acceleration of gravity,

$$\text{therefore: } m = \frac{F_w}{g}$$

Since g is not a constant, but varies with distance from the gravitational center of the earth, the weight of a body is not constant.

C. Units of Mass and Weight in the Gravitational and Absolute Systems

1. Units for Force in the Absolute System of Measurement

In establishing the basis for the development of derived physical quantities we begin with three Undefined Physical Quantities:

Length, Time, and Force (or mass)*

*If force is considered to be undefined, mass may be defined as RF/acceleration. If mass is considered to be undefined force may be defined as mass x acceleration (F=ma).

At this point our understanding of the concept of mass is still rather fuzzy. As convention dictates, however, one should consider force to be defined (F = ma) and mass as being undefined.

2. Universally Agreed Upon Force Units

a. Gravitational System

(1) FPS

(2) CGS

(3) MKS

b. Absolute System

(1) FPS

(2) CGS

(3) MKS

GRAVITATIONAL UNITS

QUANTITY	FPS	CGS	MKS
Length (d, s, h)	ft.	cm	m
time (t)	sec	sec	sec
force (F_x)	lb	g	Kg
mass ($m = \frac{F}{g}$)	$\frac{\text{lb-sec}^2 = \text{slug}}{\text{ft}}$	———	———
work ($W = F \cdot d_n$)	ft-lb	———	———
power ($P = \frac{W}{t} = \frac{F \cdot d_n}{t}$	$\frac{\text{ft-lb}}{\text{sec}}$	———	———

ABSOLUTE UNITS

QUANTITY	FPS	CGS	MKS
Length (d, s, h)	ft	cm	m
time (t)	sec	sec	sec
force $F = ma$	lb-ft/$_{\text{sec}^2}$= poundal	$\frac{\text{g-cm}}{\text{sec}^2}$ = dyne	$\frac{\text{Kg-m}}{\text{sec}^2}$ = Nt
mass (m)	lb	g	Kg
work ($F \cdot d$)	$\frac{\text{lb-ft}^2}{\text{sec}^2}$ = poundal ft	dyne-cm = erg	$\underline{\text{Nt-m}}$ = joule
power ($P = \frac{w}{t}$)	$\frac{\text{lb-ft}}{\text{sec}^3} = \frac{\text{poundal-ft}}{\text{sec}}$	$\frac{\text{dyne-cm}}{\text{sec}} = \frac{\text{erg}}{\text{sec}}$	$\frac{\text{Nt-m}}{\text{sec}} = \frac{\text{joule}}{\text{sec}}$ = watt

3. Conversion of Units and Values Between the Gravitational and Absolute Systems

a. General Basis of Conversion

FPS
CGS
MKS

b. Variations in the value of "g"

IV. Universal Gravitation

A. Concept of Weight Prior to 1700

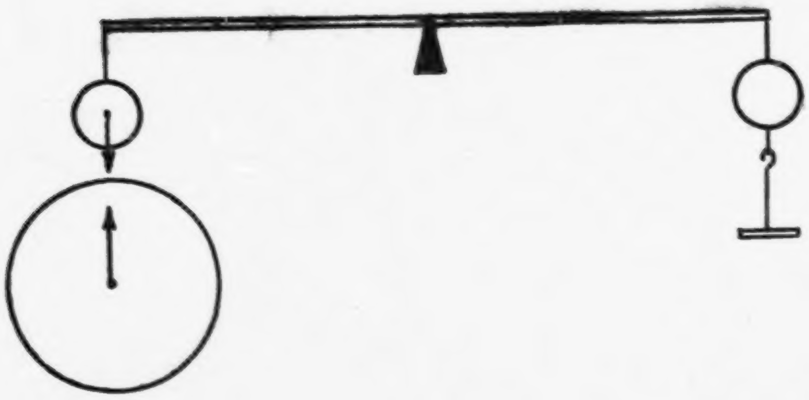
1. Weight an inherent property of matter unique to the earth

2. Newton's concept of gravity vs. weight
(Sir Isaac Newton 1642-1727)

B. Present Concept of Weight

1. $\frac{F_w}{\text{"g"}}$ = constant, universal property of all matter

2. Universal gravitation



$$F \overset{\propto}{=} \frac{m_1 m_2}{d^2}$$

C. The Universal Gravitational Constant

1. Establishment of a Constant to Agree with the Arbitrary Standards for Weight

$$F_w = \frac{m_1 m_2}{d^2}$$

$$F_w = \frac{G m_1 m_2}{d^2}$$

$$G = \frac{F_w d^2}{m_1 m_2}$$

2. Determination of the Gravitational Constant (G)

   a. Henry Cavendish (1731-1810)

   b. Gravitational and Absolute Values for G

47

MANNED ORBITAL FLIGHT STATISTICS

Astronaut	Nation	Spacecraft	Date	No. of orbits	Altitude at, mi.		Duration of flight	Spacecraft launch wt., lb	Rocket Thrust, lb
					Perigee	Apogee			
Gagarin	U.S.S.R.	Vostok I	April 12—April 12, 1961	1	112.5	203	1 hr 48 min	10,418*	800,000*
Titov	U.S.S.R.	Vostok II	Aug. 6—Aug. 7, 1961	17.5	113.1	151.7	25 hr 18 min	10,430*	800,000*
Glenn	U.S.	Friendship 7	Feb. 20—Feb. 20, 1962	3	100.3	162.7	4 hr 55 min	4,265	360,000
Carpenter	U.S.	Aurora 7	May 24—May 24, 1962	3	100	166.8	4 hr 56 min	4,244	360,000
Nikolayev	U.S.S.R.	Vostok III	Aug. 11—Aug. 15, 1962	64	112.3	145.6	91 hr 22 min	10,430	800,000*
Popovich	U.S.S.R.	Vostok IV	Aug. 12—Aug. 15, 1962	48	111.7	147.1	70 hr 57 min	10,430	800,000*
Schirra	U.S.	Sigma 7	Oct. 3, 1962	6	100	176	9 hr 13 min	4,325	360,000
Cooper	U.S.	Faith 7	May 15—May 16, 1963	22	100.2	166.1	34 hr 20 min	4,000	360,000
Bykovsky	U.S.S.R.	Vostok V	June 14—June 19, 1963	81	99	46	119 hr 6 min	10,430	800,000*
Tereshkova	U.S.S.R.	Vostok VI	June 16—June 19, 1963	48	108	143	70 hr 50 min	10,440	800,000*
Feoktistov Komarov Yegorov	U.S.S.R.	Voskhod I	Oct. 12—Oct. 13, 1964	16	111	254	24 hr 17 min	16,000*	900,000*
Belyayev Leonov	U.S.S.R.	Voskhod II	Mar. 18—Mar. 19, 1965	17	108	307.5	26 hr 2 min	16,000*	900,000*
Grissom Young	U.S.	Gemini 3	Mar. 23, 1965	3	101	139	4 hr 53 min	7,100	530,000
McDivitt White	U.S.	Gemini 4	June 3—June 7, 1965	62	100	184	97 hr 48 min	7,800	530,000
Cooper Conrad	U.S.	Gemini 5	Aug. 21—Aug. 29, 1965	100	101	207	190 hr 56 min	7,000	530,000
Schirra Stafford	U.S.	Gemini 6	Dec. 15—Dec. 16, 1965	16	100	193	25 hr 51 min	7,000	530,000
Borman Lovell	U.S.	Gemini 7	Dec. 4—Dec. 18, 1965	206	100	204	330 hr 35 min	8,069	533,000
Armstrong Scott	U.S.	Gemini 8	Mar. 16, 1966	6.6	99	186	10 hr 42 min	8,351	533,000
Stafford Cernan	U.S.	Gemini 9	June 3—June 6, 1966	44	100	194	72 hr 21 min	8,100	533,000
Young Collins	U.S.	Gemini 10	July 18—July 21, 1966	43	100	476	70 hr 47 min	8,250	533,000
Conrad Gordon	U.S.	Gemini 11	Sept. 12—Sept. 15, 1966	44	99	851	71 hr 17 min	8,260	533,000
Aldrin Lovell	U.S.	Gemini 12	Nov. 11—Nov. 15, 1966	59	96	168	94 hr 35 min	8,286	533,000

*Estimated.

One Reason Why They're So Expensive

Spacecraft and high speed aircraft are expensive! One reason is that they must be made from very special materials that can stand up under great ranges of temperature, vibration and acceleration. Ordinary metals can't take this punishment. Fortunately aerospace metallurgists have developed new "exotic" super alloys that won't melt, shatter or change shape under the stresses of hypersonic flight or space environment.

Aerospace designers have found that these miracle metals are so hard that ordinary saws and drills cannot cut or bore through them. New ways had to be found to fashion them into the shapes and pieces required by the blueprints.

Forming these exotic metals is accomplished in several ways:
1) by underwater explosion, using the powerful shock waves that travel through water to flatten the toughest metals against a die cast pattern.

2) by large electrical discharges that compress a boundary layer of molecules and accelerate the metal into a die cavity. Electrical energy equal to the output of three Grand Coulee dams is sometimes concentrated to smash metals into the die shape in a few microseconds.

3) by electrochemical process in which salt water and an electric current eat away at the metal's surfaces wherever they are deliberately exposed.

4) by impact in which metal projectiles are shot through a 20-foot "cannon" into a forming tool. Rivets and bolts are formed through this process.

A variation of this method uses a special gun and a projectile which, when fired, crashes into a die filled with powdered metal alloy. This compresses the powder into a solid metal form combining several kinds of materials that otherwise are impossible to mix into a solid state.

Today exotic metals are used in about five per cent of aerospace products. However, by 1970 this figure is expected to rise to 90 per cent reflecting the coming costly supersonic transport, hypersonic rocket powered aircraft, and long term missions in space.

Problem Assignment

Name ____________________________

Science IIIA Hour ____

Date ____________________________

INTERACTIONS IN DYNAMIC SYSTEMS

(Resultant Force ≠ to Zero)

1. An object which has a mass of 3-Kg is accelerated upward at the rate of 5m/sec^2. What force acted on the object to produce this acceleration? In what direction did the force act?

2. What is the mass of a person who weighs 160 pounds at a point where the acceleration due to the gravitational force of the earth is 9.8 m/sec^2?

3. How long must a force of 5nt act on a body whose mass is 4-Kg to impart to it a final velocity of 20 cm/sec.?

4. The jet velocity of a rocket is 6000 ft/sec. If 1300 pounds of gas are expelled in the exhaust per second, what thrust force is developed by the rocket? Assume that the rocket is operating at 100 percent efficiency and that the velocity of the rocket equals the initial velocity of the gas molecules.

5. A mass of 2 g is acted upon by a force of 30 dynes. Find the acceleration produced. What acceleration would be produced if a force of 30 g acted upon the same mass?

6. An 80 lb. force acts upon a mass of 20 lbs. Calculate:

   a. the acceleration produced

   b. the acceleration produced if a force of 80 lbs. acts upon a body having a weight of 20 lbs.

7. A car, weighing 2000 lbs. is traveling with a velocity of 60 mi/hr. Calculate the magnitude of the retarding force of the brakes necessary to bring the car to rest in 220 feet.

8. A gun, weighing 500 lbs., mounted on wheels, shoots a projectile which weighs 25 lbs. The projectile leaves the muzzle of the gun at an angle of 30 degrees and with an initial velocity of 2000 ft/sec. Calculate the horizontal recoil velocity of the gun.

Extra Credit Problems

Name ______________________
Science IIIA Hour ______
Date Due __________________

INTERACTIONS IN DYNAMIC SYSTEMS

1. A cord passing over a "frictionless pulley" has a 7-g mass tied on one end and a 9-g mass on the other. Find the resulting acceleration and the tension in the cord.

2. An object is suspended from the roof of an elevator car by means of a spring balance. The balance reads 45 pounds while the car is being accelerated upward at the rate of 4 ft/sec^2. Find:

   a. the weight of the object when the car is at rest -

   b. under what conditions will the spring balance read 35 pounds -

   c. what will the balance read if the elevator cable breaks -

THE QUANTITATIVE RELATIONSHIP BETWEEN WORK AND ENERGY

INTRODUCTION:

In our initial development of ideas associated with the concept of work and energy, work was defined as the product of force and distance, $w = F \cdot d$ (F//d), and energy as the equivalent of work. Our investigations at that time were limited to the simple case where the force was equal to the weight of a body. The work-energy relationship was restricted to the equivalence between the work done in lifting a body above the surface of the earth and the potential energy gained by the body as a result of the work done.

More recently we have been developing ideas about matter-energy relationships involving resultant forces and the conditions which determine the equilibrium state of matter. We have already established several fundamental ideas about such systems:

1. all systems involve matter which is subjected to the influence of two or more forces acting simultaneously,
2. the resultant force acting upon a body must be found by vector addition - the resultant force is either zero or it is not,
3. if the vector sum of all forces acting on a body within a closed system is zero, the body is in equilibrium,
4. a system which is in equilibrium can be either static (at rest) or dynamic (in motion with constant velocity),
5. if the resultant force acting upon a body is not zero, the system is not in equilibrium - the body will be in motion and will experience acceleration:

$$a = \frac{RF \text{ (not zero)}}{m}$$

In order to describe the work - energy relationship for systems such as these, it becomes necessary to find some means of equating the work done by a body which is in motion.

If a body is in motion, either with constant velocity or accelerating, it possesses KINETIC ENERGY. A body which is at rest possesses only POTENTIAL ENERGY. In this experiment we shall try to establish a quantitative relationship between the work done on a body in order to set it in motion and the kinetic energy gained by the body as a result of the work done.

The basis for establishing this relationship is the fundamental law of conservation of matter and energy. Experience with this natural law suggests that any given quantity of potential energy can be represented

52 in terms of an equivalent amount of kinetic energy. In our experiment we shall determine the work done in raising the potential energy of a body to a given level. Having established the magnitude of the potential energy gained, this energy will then be converted to kinetic energy. The energy stored in the body will be used to set the body into motion. The purpose of the experiment is to provide data which will permit us to describe the kinetic energy possessed by the moving body in terms of its weight or mass and its rate of motion.

PROBLEM:

What is the relationship between the laws which describe the motion of a body and the kinetic energy possessed by the body by virtue of its motion?

Laboratory Problem

Name ______________________________

Science IIIA Hour _____

Date ______________________________

THE QUANTITATIVE RELATIONSHIP BETWEEN WORK AND ENERGY

I. Set up an inclined plane. Determine the coefficient of sliding friction for a wood block moving along the surface. Prepare a vector diagram representing the magnitude and direction of all forces and also the angle and distances involved in the experiment.

DATA (Vector Diagram)

CALCULATIONS (show only the equations used and substitution of values)

μ = ☐

II. Work - energy relationship with RF = 0, **motion with constant velocity.** Adjust the incline to an angle of 30°. **Calculate the work that would have to be done in order to slide the block upward,** along the incline, **a distance** equal to the length of the board, minus, the length of the block.

DATA (Vector Diagram)

CALCULATIONS

w = ☐

A. Calculate the work that would have to be done on the block in order to lift it vertically to the same height. NOTE: $h = \sin 30^\circ \cdot$ (length of incline - length of block)

w =

CALCULATIONS:

B. Neglecting the work done in overcoming the friction force, how much work was done in sliding the block up the incline? NOTE: $d = 1 -$ length of block

w =

CALCULATIONS

C. How much potential energy was gained by the block as a result of moving it to the upper part of the incline?

PE Gained =

CALCULATIONS

III. Work - energy relationship with $RF \neq 0$, motion with acceleration. Without changing the angle of the incline, start the block from a "rest" position with the end of the block flush with the upper end of the board and measure the time required for the block to slide to bottom. Take the average of at least five trials.

DATA:

Trial #	Time (sec)
1	
2	
3	
4	
5	

F_w (block) ________

d (1-length of block) ________

μ ________

∠ of incline ________

t (avg. of 5 trials) ________

INTERPRETATION OF DATA (continued)

With reference to the block in part III, calculate:

A. final velocity

v =

Calculations: Include only the equations used and substitution of values.

B. the acceleration, based on an initial velocity equal to zero

a =

C. the mass of the block (assume that "g" = 980 cm/sec^2

m =

D. the resultant force responsible for the acceleration

RF =

E. the total work done by the block as it accelerated down the incline

w =

CONCLUSIONS:

Use quantitative data to point out the relationship between the work done by the block while accelerating down the incline and the kinetic energy of the block in terms of its final velocity and mass.

WORK DONE	KINETIC ENERGY

QUESTIONS:

1. Identify the physical quantities which have an affect on the kinetic energy possessed by a body.

2. Under what conditions does a body posses kinetic energy?

3. Can a body which is in equilibrium possess kinetic energy?

4. Give the units for the following:

	GRAVITATIONAL (FPS)	ABSOLUTE (CGS)
kinetic energy		
potential energy		
work		

Problems

Name ____________________________

Science IIIA Hour ____

Date ________________________

WORK - POWER - ENERGY

1. A small hoist is used to raise a 100-kg weight to a height of 2 meters. Calculate the work done.

2. A 110 pound block is pushed a distance of 20 feet along the floor at constant speed by a force exerted at an angle of 30 degrees with the horizontal. The coefficient of friction between the block and the floor is 0.24. How much work is done?

3. A 15 pound object is lifted vertically with a constant velocity of 10 feet per second through a distance of 20 feet. How much work is done on the block?

4. What average horsepower is developed by a man, weight 180 pounds, when climbing a rope 20 feet long in 12 seconds? Express this amount in watts.

5. The locomotive of a freight train exerts a constant force of 5 tons on the cars while drawing the train at a speed of 40 miles per hour over level track. What horsepower is developed by the locomotive?

6. What is the potential energy of a 1600 pound elevator at the top of the Empire State Building, 1248 feet above street level? Assume the potential energy at street level is zero.

7. A 500 pound ball is dropped from a height of 4 feet in order to break up a concrete road. What potential energy is possessed by the ball before it is dropped? What is its kinetic energy when it strikes the concrete?

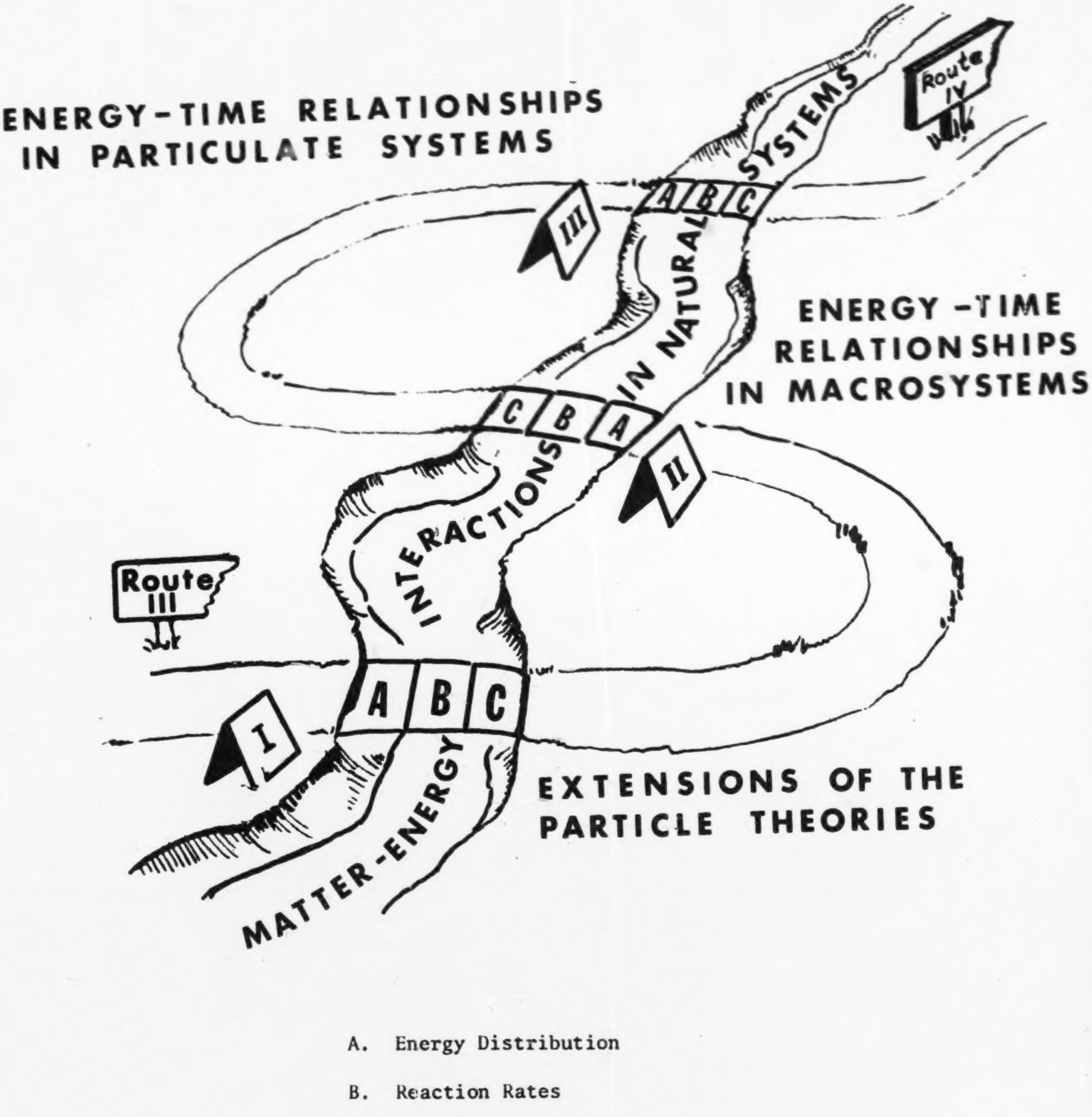
8. A mine is 150 meters deep. If an engine can hoist 200 metric tons of ore from this mine in 10 hours, what is the rating of the engine in kilowatts? In horsepower?

EXTRA CREDIT PROBLEMS:

9. If energy costs 5 cents per kilowatt hour, how much is one horsepower hour worth?

10. An elevator, with its load, weighs 2400 pounds. The elevator starts from rest at the first floor, six seconds later it passes the fifth floor, 64 feet above the first. The velocity at this moment is 21.3 feet per second. Calculate the work done on the elevator during this six second interval. What was the average horsepower developed?

SCIENCE IIIA


Route IV
ENERGY-TIME RELATIONSHIPS IN PARTICULATE SYSTEMS
III
A B C
SYSTEMS
MATTER-ENERGY INTERACTIONS IN NATURAL SYSTEMS
ENERGY-TIME RELATIONSHIPS IN MACROSYSTEMS
C B A
II
Route III
A B C
I
EXTENSIONS OF THE PARTICLE THEORIES

A. Energy Distribution

B. Reaction Rates

C. Equilibrium in Particulate Systems

Energy - Time Relationships in Particulate Systems

ENERGY DISTRIBUTION

Energy Changes in Reactions

Activation Energy

Reaction Pathways

Resource Material

ENERGY DISTRIBUTION

Required Reading:	Modern Chemistry, (1966 Edition), Chemical Kinetics, pages 332-346
Recommended Reading:	Chemistry, An Experimental Science, Energy Effects In Chemical Reactions, pages 108-119

QUESTIONS FOR CONSIDERATION:

1. Why is it impossible to measure heat content directly?

2. In what ways may energy be stored in a molecule?

3. The assigned heat content for each free element in its reference state is zero. Does this indicate that the energy stored in, for example, the gaseous element hydrogen, is zero at 25°C and 1 atmosphere pressure?

4. How does Hess's law of heat summation (additivity of reaction heats) represent the law of conservation of energy?

5. What evidence can be cited to show that a substance has a characteristic internal energy?

ENERGY DISTRIBUTION

I. Energy Changes in Reactions

  A. Internal Energy - energy storage in a substance

  B. Energy Effects in Physical Change

    1. Changes of State

    2. Heat of Solution

  C. Energy Effects in Chemical Change

    1. Heat Content

    2. Heat of Reaction

      a. the standard state

b. heat of formation

c. heat of combustion

d. additivity of reaction heats

e. measurement of reaction heat

f. predicting the heat of a reaction

D. Driving force of reactions

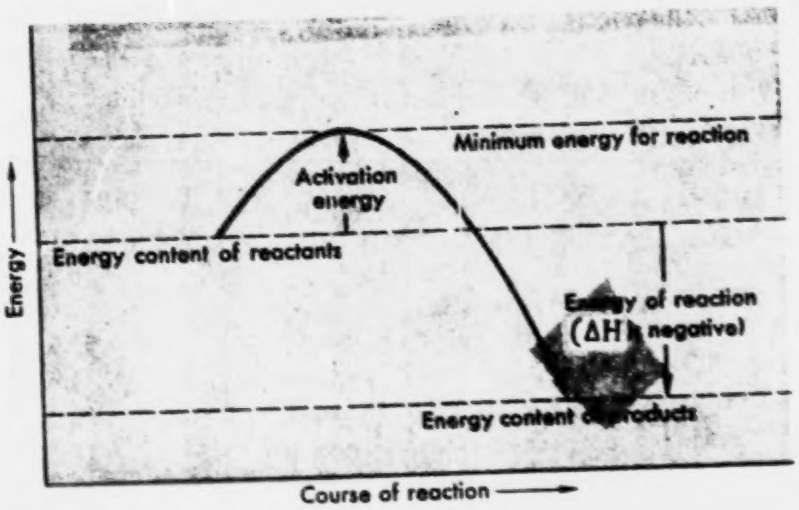
II. Activation Energy

A. Collision Theory

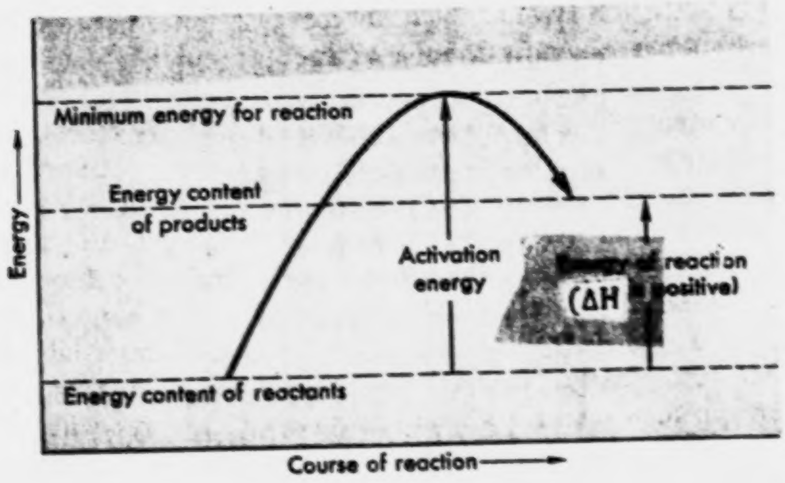
B. The Activated Complex

III. Reaction Pathways

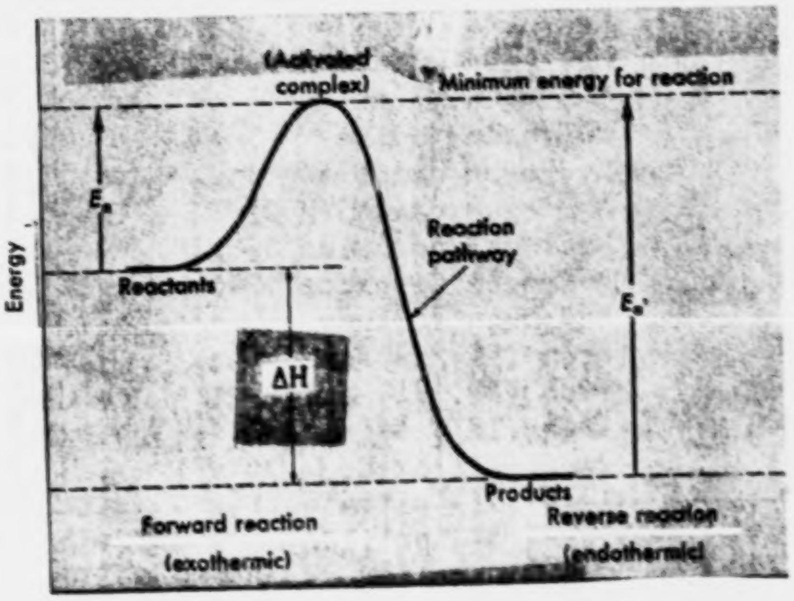
A. Exothermic Reaction


Minimum energy for reaction
Activation energy
Energy content of reactants
Energy
Energy of reaction
(ΔH is negative)
Energy content of products
Course of reaction

B. Endothermic Reaction


Minimum energy for reaction
Energy content of products
Energy
Activation energy
Energy of reaction
(ΔH is positive)
Energy content of reactants
Course of reaction

C. Reversible Reaction


(Activated complex)
Minimum energy for reaction
E_a
Energy
Reactants
Reaction pathway
E_a'
ΔH
Products
Forward reaction (exothermic)
Reverse reaction (endothermic)

HEAT OF FORMATION TABLE

ΔH_f = heat of formation of the given substance from its elements. All values of ΔH_f are expressed as Kcal/mole at 25°C. Negative values of ΔH_f indicate exothermic reactions.

SUBSTANCE	STATE	ΔH_f
aluminum oxide	s	-399.09
ammonia	g	- 11.04
barium sulfate	s	-350.2
benzene	g	19.82
benzene	l	11.72
calcium chloride	s	-190.0
calcium hydroxide	s	-235.80
calcium oxide	s	-151.9
carbon (diamond)	s	0.45
carbon (graphite)	s	0.00
carbon dioxide	g	- 94.05
carbon disulfide	g	27.55
carbon disulfide	l	21.0
carbon monoxide	g	- 26.42
carbon tetrachloride	g	- 25.5
carbon tetrachloride	l	- 33.3
copper (II) nitrate	s	- 73.4
copper (II) oxide	s	- 37.1
copper (II) sulfate	s	-184.00
dinitrogen monoxide	g	19.49
dinitrogen pentoxide	g	3.6
dinitrogen pentoxide	s	- 10.0
dinitrogen tetroxide	g	2.31
diphosphorus pentoxide	s	-360.0
ethane	g	- 20.2
ethyne (acetylene)	g	54.19
hydrogen (H_2)	g	0.00
hydrogen bromide	g	- 8.66
hydrogen chloride	g	- 22.06
hydrogen fluoride	g	- 64.2
hydrogen iodide	g	6.20
hydrogen oxide (H_2O)	g	- 57.80
hydrogen oxide (H_2O)	l	- 68.32
hydrogen peroxide	g	- 31.83
hydrogen peroxide	l	- 44.84
hydrogen sulfide	g	- 4.82
iron (II) sulfate	s	-220.5
iron (II,III) oxide	s	-267.0
iron (III) oxide	s	-196.5
lead (II) oxide	s	- 52.07
lead (II) nitrate	s	-107.35
lead (II) sulfide	s	- 22.54
magnesium chloride	s	-153.40
magnesium oxide	s	-143.84
mercury (II) chloride	s	- 55.0
mercury (II) fulminate	s	64.
mercury (II) nitrate	s	- 93.0
mercury (II) oxide	s	- 21.68
methane	g	- 17.89
nitrogen dioxide	g	8.09
nitorgen monoxide	g	21.60
oxygen (O_2)	g	0.00
ozone (O_3)	g	34.00
potassium bromide	s	- 93.73
Potassium chloride	s	-104.18
potassium hydroxide	s	-101.78
potassium nitrate	s	-117.76
potassium sulfate	s	-342.66
propane	g	- 24.8
silver chloride	s	- 30.36
silver nitrate	s	- 29.43
silver sulfide	s	- 7.60
sodium bromide	s	- 86.03
sodium chloride	s	- 98.23
sodium hydroxide	s	-101.99
sodium nitrate	s	-101.54
sodium sulfate	s	-330.90
sulfur dioxide	g	- 70.96
sulfur trioxide	g	- 94.45
sulfuric acid	s	-194
tin (IV) chloride	l	-130.3
zinc nitrate	s	-115.12
zinc oxide	s	- 83.17
zinc sulfate	s	-233.88
zinc sulfide	s	- 14.0

Problem Exercise

Name ______________________________

Science IIIA Hour _____

Date ______________________________

ENERGY DISTRIBUTION

1. Use heat of formation table to predict the heat of the reaction:

$$CO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{2(g)}$$

2. $NH_{3(g)} + 7/4O_{2(g)} \rightarrow NO_{2(g)} + 3/2H_2O_{(g)}$ represents the reaction for the oxidation of ammonia. Calculate the heat of the reaction.

3. Calculate the amount of heat liberated by the formation of the following:

   a. 2.0 g of $HBr_{(g)}$ from $H_{2(g)}$ and $Br_{2(g)}$ -

   b. one molecule of $HBr_{(g)}$ from $H_{2(g)}$ and $Br_{2(g)}$ -

4. How much energy is consumed in the decomposition of 5.0 grams of $H_2O_{(l)}$ at 25°C and 1 atmosphere into its gaseous elements at 25°C and one atmosphere?

5. Given:

$$C(diamond) + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = -94.50 \text{ kcal}$$

$$C(graphite) + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = -94.05 \text{ kcal}$$

   a. find ΔH for the manufacture of diamond from graphite -

   b. is heat absorbed or evolved as graphite is converted to diamond?

   c. how do you account for the great difficulty found in the industrial process for accomplishing this?

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6. The "thermite" reaction is spectacular and highly exothermic. It involves the reaction between Fe_2O_3, ferric oxide, and metallic aluminum. The reaction produces white-hot, molten iron in a few seconds. Given:

$$2Al + 3/2O_2 \rightarrow Al_2O_3$$

$$2Fe + 3/2O_2 \rightarrow Fe_2O_3$$

a. Determine the amount of heat liberated in the reaction of 1 mole of Fe_2O_3 with Al.

b. How much energy is released in the manufacturing of 1.00 kg of iron by the "thermite reaction"?

c. How many grams of water could be heated from 0°C to 100°C by the heat liberated per mole of aluminum oxide formed in the reaction?

7. Which would be the better fuel on the basis of the heat released per mole burned: nitric oxide (NO) or ammonia (NH_3)? Assume the products are $NO_{2(g)}$ and $H_2O_{(g)}$.

8. What is the minimum energy required to synthesize sulfur dioxide from sulfuric acid?

$$H_2SO_{4(l)} \rightarrow SO_{2(g)} + H_2O_{(g)} + \frac{1}{2}O_{2(g)}$$

Laboratory Problem

THE HEAT OF FORMATION OF SOLID AMMONIUM CHLORIDE

INTRODUCTION:

The heat of formation of a given substance can be calculated using temperature measurements made when known quantities of materials react to form a known quantity of the substance. The equation

$$\tfrac{1}{2}N_{2(g)} + 2H_{2(g)} + \tfrac{1}{2}Cl_{2(g)} \rightarrow NH_4Cl_{(s)}$$

represents the formation of solid ammonium chloride from its component elements. In this system, each gas is present in its standard state, that is, at 1 atmosphere of pressure and 25°C. The ΔH for this reaction is called the heat of formation of solid ammonium chloride, because the equation represents the formation of 1 mole of NH_4Cl from its component elements at 25°C and one atmosphere of pressure.

Even though the equation suggests a possible reaction that should provide data for the heat of formation of the desired product, this particular reaction cannot be easily investigated in the laboratory. However, the quantity of heat energy which is released or absorbed by a reaction does not depend on the number or sequence of steps followed but only on the initial and final states of the system. In studying a given process several reactions which, taken together eventually yield the final product, may be considered and the corresponding heats of reaction can be added or subtracted to give the value for the desired heat of reaction. It is this method which must be used when the reaction cannot be directly run in the laboratory.

PROBLEM:

Determine the heat of formation of solid ammonium chloride using:

a. the heat of formation of ammonium hydroxide (aq) from its elements. (literature value = -87.64 kcal/mole)
b. the heat of formation of hydrogen chloride (aq) from its elements. (literature value = -40.02 kcal./mole)
c. the heat of reaction of ammonium hydroxide (aq) and hydrochloric acid (hydrogen chloride (aq)). (calculated form experimental data)
d. the heat of solution of solid ammonium chloride in water. (calculated from experimental data)

PROCEDURE:

Write chemical equation for all reactions mentioned in the problem. Add these equation together to determine if the net equation is the same as the overall equation given in the introduction.

Construct a calorimeter using a 250-ml beaker placed inside a 400-ml beaker, separating the beakers with newspaper packing for insulation. Use this calorimeter to find the temperature change produced when 100.0-ml of 1.5M ammonium hydroxide reacts with 100.0-ml of 1.5M hydrochloric acid.

Calculate the mass of ammonium chloride that would be required to prepare 200.0-ml of a solution with the same concentration as that of the reaction of ammonium hydroxide and hydrochloric acid. Find the temperature change when this calculated mass of ammonium chloride is added to 200.0-ml of water. Use the accumulated data, experimental and literature values, to calculate the heat of formation for solid ammonium chloride.

DATA:

Energy - Time Relationships in Particulate Systems

REACTION RATES

Factors Influencing Rate of Reaction

Law of Mass Action

REACTION RATES

Required Reading: Modern Chemistry, (1966 Edition) pages 346-351

Recommended Reading: Chemistry, an Experimental Science, pages 124-139
Fundamentals of General Chemistry, Sorum, pages 268-272

QUESTIONS FOR CONSIDERATION:

1. Explain why increasing the concentration of a reactant may cause an increase in the rate of reaction.

2. Consider two gases X and Y in a container at 25°C. What effect will the following changes have on the rate of reaction between these gases?

   a. the pressure is cut in half -

   b. the number of molecules of gas X is doubled -

   c. the temperature is increased; volume remaining constant -

3. The binding of the science books involves the following processes: collating (arranging the pages in order), punching (16 pages at a time, automatic operation), and binding. It takes as much time to punch as it does to bind. The collating takes twice as long. Which is the rate determining step?

   The collating is comprised of a step in which 8 pages are arranged in order with a machine and then those eight pages in turn are picked up in order by hand. If four people are used, then is the rate at which books are completed faster?

   Which is the determining step now?

   How could the rate of production (as judged by the number of books finished) be increased?

4. What is the collision theory?

5. In a collision of particles, what is the primary factor which determines whether a reaction will occur?

6. Name the factors which effect the rate of reaction of a chemical change.

7. In the reaction

$$4HBr_{(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)} + 2Br_{2(g)}$$

   indicate whether an increase, decrease, or no effect will result on the rate if:

   a. the HBr concentration is increased -
   b. the pressure of the gases is decreased -
   c. the temperature is increased -
   d. the Br_2 is removed as fast as it is made -

REACTION RATES

I. Rate of Reaction

  A. Definition of Rate of Reaction

  B. Measurement of Rate of Reaction

II. Collision Theory of Reaction Rate (Model)

  A. General

    1. Collision Frequency

    2. Orientation

    3. Collision Efficiency

  B. Reaction Mechansim

III. Factors Influencing the Rate of Reaction

A. Nature of Reactants

1. Nature of Bonding

2. Energy State

B. Temperature

C. Particle Size

D. Catalysts

E. Concentration

IV. Law of Mass Action

The laboratory problem on page 71-73 may be found:

TITLE Chemistry, An Experimental Science

AUTHOR Chemical Education Material Study

PUBLISHER W. H. Freeman & Company

PAGE NUMBER 41-42

EQUILIBRIUM IN PARTICULATE SYSTEMS

Qualitative Aspects of Equilibrium

Quantitative Aspects of Equilibrium

Equilibrium in Aqueous Solution

Equilibrium in Particulate Systems

Resource Material

QUALITATIVE AND QUANTITATIVE ASPECTS OF EQUILIBRIUM

Required Reading:	Modern Chemistry, (1966 edition), Chemical Equilibrium, pages 354-364
Recommended Reading:	Chemistry, An Experimental Science, Equilibrium in Chemical Reactions, pages 142-160

QUESTIONS FOR CONSIDERATION:

1. What is the difference between dynamic and static equilibrium systems?

2. Which of the following situations represent systems in dynamic equilibrium? Which represent static equilibrium systems?
    a. Atoms of liquid mercury and mercury vapor in a thermometer. Temperature is constant.
    b. A car traveling with a constant velocity.
    c. A block of wood floating on still water.
    d. During the noon hour, the water fountain constantly has a line of persons.

3. Why are chemical equilibria referred to as dynamic?

4. In any discussion of chemical equilibrium, why are concentrations always expressed in moles rather than in grams, per unit volume?

5. What factors disturb or shift an equilibrium? Which of these affects the value of the equilibrium constant?

6. How does a catalyst affect the equilibrium conditions of a chemical system?

7. One drop of water may or may not establish a state of vapor pressure equilibrium when placed in a closed bottle. Explain.

Equilibrium in Particulate Systems

QUALITATIVE ASPECTS OF EQUILIBRIUM

I. The State of Equilibrium in Particulate Systems

   A. Examples

   B. Characteristics

II. Factors Which Determine the Point at Which Equilibrium is Established

III. Altering the State of Equilibrium

A. Factors Which Disturb Equilibrium

B. Le Chatelier's Principle

IV. Application of Equilibrium Principle

The laboratory problem on pages 77-79 may be found

TITLE Chemistry, An Experimental Science

AUTHOR Chemical Education Material Study

PUBLISHER W. H. Freeman & Company

PAGE NUMBER 43-45

Name ______________________

Science IIIA Hour ____

Date ______________________

SAMPLE DATA AND CALCULATION TABLE

COLUMN
1. Initial concentration of Fe^{+3}(aq) after one to one dilution.
2. Initial concentration of SCN^-(aq) after one to one dilution.
3. Ratio = depth in standard tube/depth in nonstandard tube when the two are matched.
4. Equilibrium concentration of $FeSCN^{+2}$ (aq) obtained by multiplying ratio (column 3) by initial concentration of SCN^-(aq).
5. Equilibrium concentration of Fe^{+3}(aq) obtained by subtracting equilibrium concentration of $FeSCN^{+2}$(aq) (column 4) from initial concentration of Fe^{+3}(aq) column 1).
6. Equilibrium concentration of SCN^-(aq) obtained by subtracting equilibrium concentration of $FeSCN^{+2}$(aq) (column 4) from initial concentration of SCN^-(aq) (column 2).

Tube #	1 Initial (Fe^{+3})	2 Initial (SCN^-)	3 Ratio	4 Equil. ($FeSCN^{+2}$)	5 Equil. (Fe^{+3})	6 Equil. (SCN^-)	Numerical Relationships of Equilibrium Concentrations		
							(A)	(B)	(C)

Equilibrium in Particulate Systems

QUANTITATIVE ASPECTS OF EQUILIBRIUM

I. The Law of Chemical Equilibrium

A. Derivation from Equilibrium Data

B. Derivation from Rates of Opposing Reactions

II. The Equilibrium Constant

A. Equilibrium Constant Calculations

B. Importance of Equilibrium Constants

Name ______________________________

Exercise

Science IIIA Hour _____

Date ________________________

EQUILIBRIUM

1. The following chemical equation represents the reaction between hydrogen and chlorine to form hydrogen chloride:

$$H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)} + 44.0 \text{ kcal.}$$

a. List four important pieces of information conveyed by this equation.

b. What are three important areas of interest concerning this reaction for which no information is indicated?

2. If the phase change represented by

$$\text{heat} + H_2O_{(l)} \rightleftarrows H_2O_{(g)}$$

has reached equilibrium in a closed system:

a. What will be the effect of a reduction of volume, thus increasing the pressure?

b. What will be the effect of an increase in temperature?

c. What will be the effect of injecting some steam into the closed system, thus raising the pressure?

3. Methanol (methyl alcohol) is made according to the following net equation:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{heat}$$

Predict the effect on equilibrium concentrations of an increase in:

a. temperature

b. pressure

4. Consider the reaction:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + 27 \text{ kcal.}$$

What effect would the following changes have on the equilibrium concentration of Cl_2? Give your reasons for each answer.

a. Increasing the temperature of the reaction vessel

b. Decreasing the total pressure

c. Increasing the concentration of O_2

d. Increasing the volume of the reaction chamber

e. Adding a catalyst

5. Each of the following systems has come to equilibrium. What would be the effect on the equilibrium concentration (increase, decrease, no change) of each substance in the system when the listed reagent is added?

REACTION	REAGENT
a. $C_2H_{6(g)} \rightleftarrows H_{2(g)} + C_2H_{4(g)}$	$H_{2(g)}$
b. $Cu^{+2}_{(aq)} + 4NH_{3(g)} \rightleftarrows Cu(NH_3)^{+2}_{4(aq)}$	$CuSO_{4(s)}$
c. $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightleftarrows AgCl_{(s)}$	$AgCl_{(s)}$
d. $PbSO_{4(s)} + H^{+}_{(aq)} \rightleftarrows Pb^{+2}_{(aq)} + HSO^{-}_{4(aq)}$	$Pb(NO_3)_{2(solution)}$
e. $CO_{(g)} + \frac{1}{2}O_{2(g)} \rightleftarrows CO_{2(g)} + \text{heat}$	heat

6. Nitric oxide, NO, releases 13.5 kcal/mole when it reacts with oxygen to give nitrogen dioxide. Write the equation for this reaction and predict the effect of increasing the temperature and of increasing the concentration of NO (at a fixed temperature) on:

a. the equilibrium concentration

b. the numerical value of the equilibrium constant

c. the speed of formation of NO_2

7. Given:

$$SO_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightleftarrows SO_{3(g)} + 23 \text{ kcal}$$

a. For this reaction discuss the conditions that favor a high equilibrium concentration of SO_3.

b. How many grams of oxygen gas are needed to form 1.00 gram of SO_3?

8. Write the expression indicating the equilibrium law relations for the following reactions.

a. $N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$

b. $CO_{(g)} + NO_{2(g)} \rightleftarrows CO_{2(g)} + NO_{(g)}$

c. $Zn_{(s)} + 2Ag^{+}_{(aq)} \leftrightarrows Zn^{+2}_{(aq)} + 2Ag_{(s)}$

d. $PbI_{2(s)} \rightleftarrows Pb^{+2}_{(aq)} + 2I^{-}_{(aq)}$

e. $CN^{-}_{(aq)} + H_2O_{(l)} \rightleftarrows HCN_{(aq)} + OH^{-}_{(aq)}$

Problem Exercise

Name ____________________
Science IIIA Hour ______
Date Due ____________________

CHEMICAL EQUILIBRIUM

1. At equilibrium at a given temperature and in a liter reaction vessel HI is 20 mole percent dissociated into H_2 and I_2, according to the equation:

$$2HI \rightleftarrows H_2 + I_2$$

If one mole of pure HI is introduced into a liter reaction vessel at the given temperature, how many moles of each component will be present when equilibrium is established?

2. PCl_5 is 20 mole percent dissociated into PCl_3 and Cl_2 at equilibrium at a given temperature and in a liter vessel in accordance with the equation:

$$PCl_5 \rightleftarrows PCl_3 + Cl_2$$

One mole of pure PCl_5 was introduced into a liter reaction vessel at the given temperature. How many moles of each compound were present at equilibrium?

3. A reaction vessel in which the following reaction had reached a state of equilibrium,

$$CO + Cl_2 \rightleftarrows COCl_2 ,$$

was found, on analysis, to contain 0.3 mole of CO, 0.2 mole of Cl_2, and 0.8 mole of $COCl_2$, in a liter mixture. Calculate the equilibrium constant for the reaction.

4. An equilibrium mixture,

$$2SO_2 + O_2 \rightleftarrows 2SO_3$$

contained in a 2-liter reaction vessel at a specific temperature was found to contain 96 grams of SO_3, 25.6 grams of SO_2 and 19.2 grams of O_2. Calculate the equilibrium constant for the reaction at this temperature.

5. In an equilibrium mixture of N_2, H_2, and NH_3, contained in a 5-liter reaction vessel at 450°C and a total pressure of 332 atmospheres, the partial pressures of the gases were: N_2 = 47.5 atmospheres, H_2 = 142.25 atmospheres, NH_3 = 142.25 atmospheres. Calculate the equilibrium constant for the reaction.

6. The equilibrium constant for the reaction

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

is 4 at a given temperature. An equilibrium mixture of the above substances at the given temperature was found to contain 0.6 mole of CO, 0.2 mole of steam, and 0.5 mole of CO_2 in a liter. How many moles of H_2 were there in the mixture?

7. Exactly one mole of NH_3 was introduced into a liter reaction vessel at a certain high temperature. When the reaction

$$2NH_3 \rightleftarrows N_2 + 3H_2$$

had reached a state of equilibrium, 0.6 mole of H_2 was found to be present. Calculate the equilibrium constant for the reaction.

8. The equilibrium constant for the reaction,

$$2SO_2 + O_2 \leftrightarrows 2SO_3$$

is 4.5 at 600°C. A quantity of SO_3 was placed in a liter vessel at 600°C. When the system reached a state of equilibrium, the vessel was found to contain 2 moles of oxygen gas. How many moles of SO_3 gas were originally placed in the reaction vessel?

Name ______________________

9. The equilibrium constant for the reaction,

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

is 2 at 300°C. A quantity of NH_3 gas was introduced into a liter reaction vessel at 300°C. When equilibrium was established, the vessel was found to contain 2 moles of N_2, therefore how many moles of NH_3 were originally introduced into the vessel?

10. The equilibrium mixture,

$$SO_2 + NO_2 \rightleftarrows SO_3 + NO$$

in a liter vessel, was found to contain 0.6 mole of SO_3, 0.4 mole of NO, and 0.1 mole of NO_2, and 0.8 mole of SO_2. How many moles of NO would have to be forced into the reaction vessel, volume and temperature being kept constant, in order to increase the concentration of NO_2 to 0.3 mole?

Equilibrium in Particulate Systems

Resource Material

EQUILIBRIUM IN AQUEOUS SOLUTIONS

Required Reading:	Modern Chemistry, (1966 Edition), Chemical Equilibrium, pages 363-373; Acids, Bases, and Salts, pages 233-237, sections 16, 17, 18.
Recommended Reading:	Chemistry, An Experimental Science, Solubility Equilibria, pages 163-176; Aqueous Acids and Bases, pages 179-195.

QUESTIONS FOR CONSIDERATION:

1. Explain why the pH of a solution containing both acetic acid and sodium acetate is higher than that of a solution containing the same concentration of acetic acid alone.

2. The ionization constant for acetic acid is 1.8×10^{-5} at 25°C. Explain the significance of this value.

3. What are the solubility characteristics of substances involved in solubility equilibrium systems?

4. Suppose 10 ml. of 1.0 M $AgNO_3$ is diluted to one liter with tap water. If the chloride concentration in the tap water is about 10^{-5} M, will a precipitate form?

5. The test described in Question 4 does not give a precipitate if distilled water is used. What is the maximum chloride concentration that could be present?

5. An acid is a substance HB that can form $H^+(aq)$ in the equilibrium

$$HB(aq) \rightleftharpoons H^+(aq) + B^-(aq)$$

   a. Does equilibrium favor reactants or products for a strong acid?

   b. Does equilibrium favor reactants or products for a very weak acid?

   c. If acid HB_1 is a stronger acid than acid HB_2, is K_1 a larger or smaller number than K_2?

EQUILIBRIUM IN AQUEOUS SOLUTIONS

I. Ionic Equilibrium

   A. Ionization Constants

   B. Common Ion Effect

II. The Nature of $H^+(aq)$

   A. Ionization Equilibrium of Water

   B. pH

   C. Hydrolysis

III. Solubility Products

Problem Exercise

Name ______________________

Science IIIA Hour ____

Date ______________________

IONIZATION CONSTANTS

1. A 0.01M solution of acetic acid is 4.17% ionized. Calculate its ionization constant.

2. Calculate the ionization constant of:

    a. a 0.1M solution of ammonium hydroxide which is 1.3% ionized -

    b. a 0.001M solution of acetic acid which is 12.6% ionized -

    c. a 0.01M solution of HCN which is 0.02% ionized -

3. a. An acid dissociated according to the equation:

$$H_2A \rightleftharpoons 2H^+ + A^{-2}$$

A 0.1M solution of the acid is 1% ionized. Calculate the ionization constant of the acid.

b. If a 0.5M solution of the weak base, MOH, contains 0.005g ion of OH^- ion in 400 ml calculate the percent ionization and the ionization constant.

c. An acid, HX, is 0.025% ionized and the concentration of H^+ ions is 5 X 10^{-5}g ions/l. Calculate the molarity of the acid.

Name ______________________________

4. The ionization constant for HCN is 4×10^{-10} at 25°C. Calculate the molarity of and the hydrogen ion concentration of a solution of HCN which is 0.01% ionized.

5. The ionization constant for ammonium hydroxide is 1.8×10^{-5}. Calculate the molarity and OH^- concentration of a solution in which the ammonium hydroxide is 1.3% ionized.

6. a. The ionization constant for acetic acid is 1.8×10^{-5}. Calculate the hydrogen ion concentration of 0.01M acetic acid.

   b. The ionization constant for Ammonium Hydroxide is 1.8×10^{-5}. Calculate the hydroxyl ion concentration of 0.1M ammonium hydroxide.

7. The ionization constant of HCN is 4×10^{-10}. Calculate the molarity of a solution of HCN which is 0.2% ionized.

Problem Exercise

Name ______________________

Science IIIA Hour ____

Date Due ________________

THE COMMON ION EFFECT

1. The ionization constant for $HC_2H_3O_2$ is 1.8×10^{-5}. How many gram ions of hydrogen ions will there be in a liter of .1 M $HC_2H_3O_2$ containing .1 mole of $NaC_2H_3O_2$? The $NaC_2H_3O_2$ is 100% ionized.

2. a. The ionization constant for NH_4OH is 1.8×10^{-5}. How many gram ions of OH^- are there in a liter of .1 M NH_4OH which contains .1 mole of NH_4Cl? The NH_4Cl is 100% ionized.

   b. The weak base, NH_4OH, has an ionization constant of 1.8×10^{-5}. What is the hydroxyl ion concentration of a solution prepared by dissolving .25 mole of NH_3 and .75 mole of NH_4Cl in enough water to make a liter of solution?

3. How many moles of NaCN must be dissolved in a liter of .2 M HCN to yield a solution with a hydrogen ion concentration of 1×10^{-6} mole per liter? The ionization constant for HCN is 4×10^{-10}.

Problem
Exercise

Name ____________________
Science IIIA Hour ____
Date Due ______________

pH AND THE IONIZATION EQUILIBRIUM OF H_2O

1. Calculate the OH^- concentration, in gram ions of OH^- per liter, of a solution which contains 1×10^{-2} g. ion of H^+ per liter. Will the solution be neutral, acidic, or alkaline?

2. Calculate the OH^- concentration, in grams of OH^- per liter, of a solution containing 1×10^{-10} g. ion of H^+ per liter.

3. a. Calculate the OH^- concentration, in grams of OH^- liter, of a solution whose H^+ concentration is:
   1. 1×10^{-6} g. ion of H^+ per liter -
   2. 3.0×10^{-4} g. of H^+ per liter -

   b. Calculate the H^+ concentration, in grams of H^+ per liter, of a solution whose OH^- concentration is:
   1. 2.0×10^{-5} g. ions of OH^- per liter -
   2. 3.4×10^{-2} g. of OH^- per liter -

4. Calculate the pH of a solution which contains 1 x 10^{-5} g. ions of H^+ per liter.

5. Calculate the pH of a solution which contains 3 x 10^{-4} g. ions of H^+ per liter.

6. Calculate the pH of a solution which contains:
   a. 1 x 10^{-8} g. ion of H^+ per liter -

   b. .0020 g. of H^+ per liter -

   c. .0030 g. ion of H^+ per liter -

   d. .00017 g. of OH^- per 100 cc. -

   e. 2.0 x 10^{-3} g. ion of OH^- per liter -

Name ____________________

7. Calculate the pH of:

   a. .01 M $HC_2H_3O_2$ which is 4.17% ionized -

   b. .10 M NH_4OH which is 4.10% ionized -

   c. .01 M KOH which is 100% ionized -

   d. .001 M H_2SO_4 which is 100% ionized -

8. Calculate the H^+ concentration in gram ions per liter of a solution whose pH is 5.

9. Calculate the H^+ concentration in gram ions per liter of a solution whose pH is 4.8.

10. Calculate the H^+ concentration in gram ions of H^+ per liter of a solution whose pH is:

    a. 1.5 -

    b. 13.6 -

11. Calculate the OH^- concentration in gram ions of OH^- per liter of a solution whose pH is:

    a. 3.6 -

    b. 6.2 -

12. Which is more strongly acid:

    a. a solution with a pH of 2, or
    b. a solution containing .02 g. of H^+ per liter

13. A .001 M solution of HF has a pH of 4. Calculate the percent ionization of the HF.

14. $BaSO_4$ is insoluble. .05 M H_2SO_4 is 100% ionized. Exactly .05 g. atoms of barium metal was added to 2 liters of .05 M H_2SO_4. When the reaction was complete what was the pH of the solution?

Laboratory

Name ____________________

Science IIIA Hour ___

Date ____________________

IONIC EQUILIBRIUM AND RATES OF REACTION

PROBLEM:

To determine how the rate of reaction is affected by ion concentration.

PROCEDURE:

1. Calculate the volume of stock acetic acid required to prepare one liter of a 0.1M $HC_2H_3O_2$ solution. The properties of the stock solution are as follows:

   SpG = 1.049
   MW = 60.06
   % Strength = 99.8%
   K_i = 1.86×10^{-5} (at 25°C)

   (Show equations, substitution of values, and final answers for all calculations. Do scratch work elsewhere.)

Volume of stock solution required = ____________________

2. Calculate the (H) for the 0.1M acetic acid solution at equilibrium; temperature = 25°C.

$$HC_2H_3O_2 \rightleftarrows H^+ + C_2H_3O_2^-$$

(H^+) 0.1M $HC_2H_3O_2$ = ____________________

3. Calculate the pH of the 0.1M acetic acid solution.

pH of 0.1M $HC_2H_3O_2$ = ____________________

4. Calculate the weight, in grams, of $NH_4C_2H_3O_2$ salt that would have to be introduced into a one liter reaction vessel containing 0.1M acetic acid in order to reduce the (H^+), by intervals of 10%, to a final concentration equal to 10% of the original value.

Name ____________________

The $NH_4C_2H_3O_2$ salt is completely soluble in water and ionizes immediately as follows:

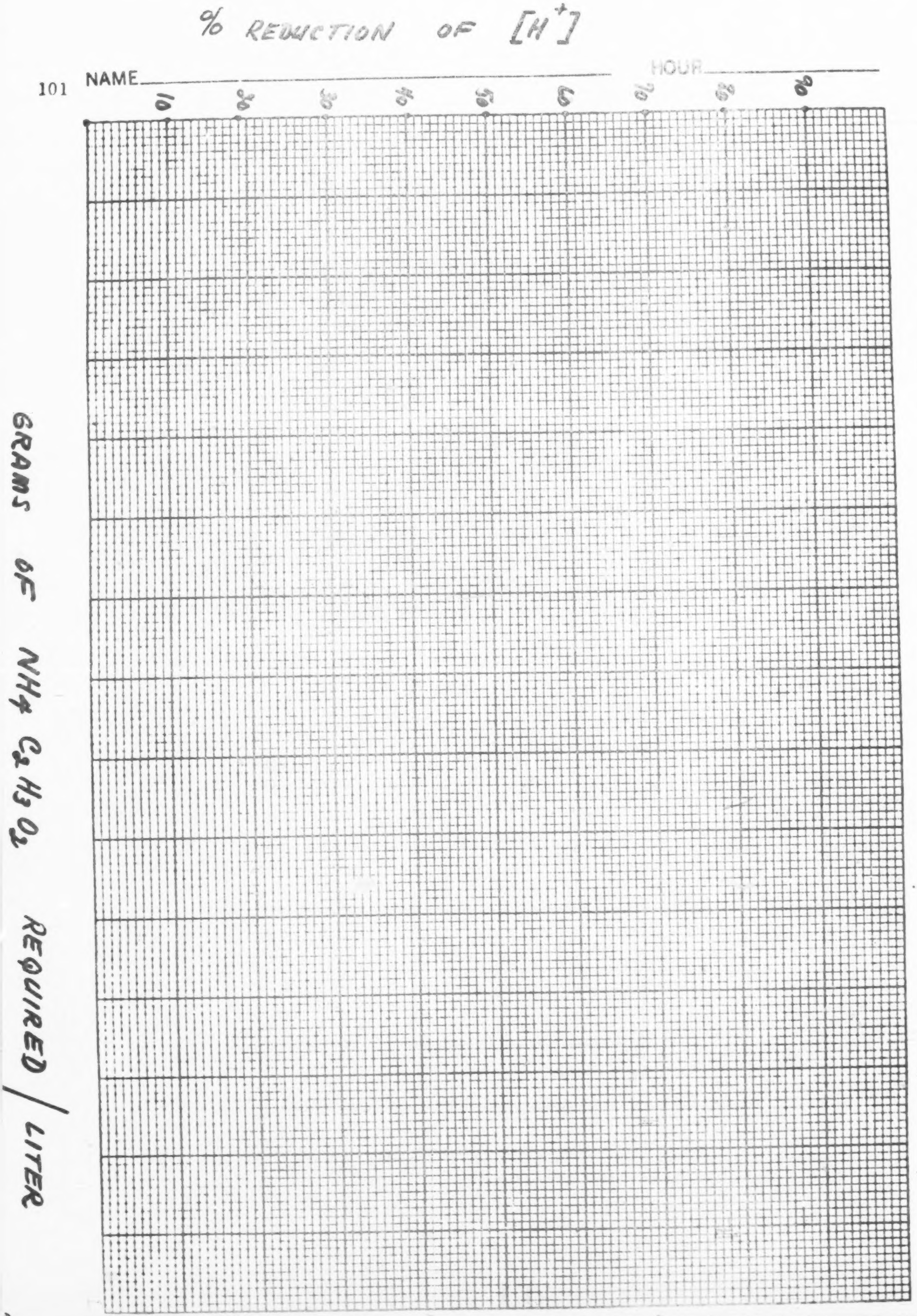
$$NH_4C_2H_3O_2 \xrightarrow{100\%} NH_4^+ + C_2H_3O_2^-$$

The molecular weight of $NH_4C_2H_3O_2$ = 77.09.

% Reduction of (H) concentration	(H) in acid $HC_2H_3O_2$ solution (25°C)	Grams $NH_4C_2H_3O_2$ required
Orig. 0.1M		
10%		
20		
30		
40		
50		
60		
70		
80		
90		
95		
99		

Prepare a graph showing reduction in (H^+) as a function of grams of $NH_4C_2H_3O_2$ added per liter of solution.

101 NAME________________ HOUR________

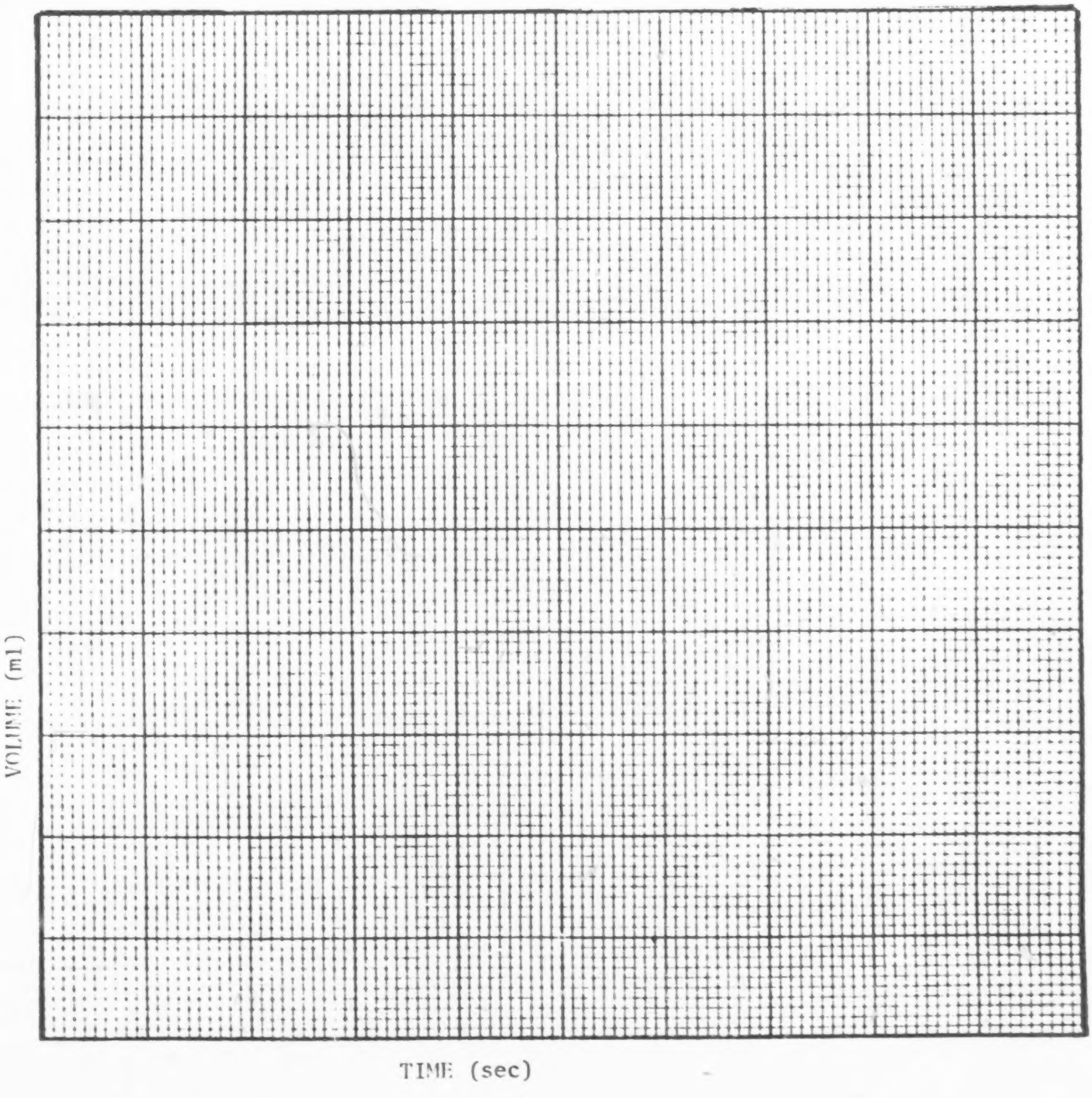


ORIGINAL [H^+] OF THE 0.1M $HC_2H_3O_2$ = ________

5. Remove the oxide coating from a strip of magnesium metal 10 centimeters long. Fill a gas measuring tube with the 0.1M acetic acid solution and support it in a 250 ml. beaker containing 200 ml. of acid solution. Coil the magnesium ribbon loosely and place it in the gas measuring tube. Invert the tube in the acid solution. Measure the rate at which hydrogen is evolved.

volume (ml)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
time (sec)															

Prepare a graph showing rate of gas evolution.



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6. Obtain 250 ml. of the standard 0.1M acetic acid solution and add enough $NH_4C_2H_3O_2$ salt to reduce the (H^+) to the assigned value. Prepare a 10 centimeter strip of magnesium ribbon as before and measure the rate at which the magnesium repalced H_2 from the acid solution.

(H) reduced to ________ %

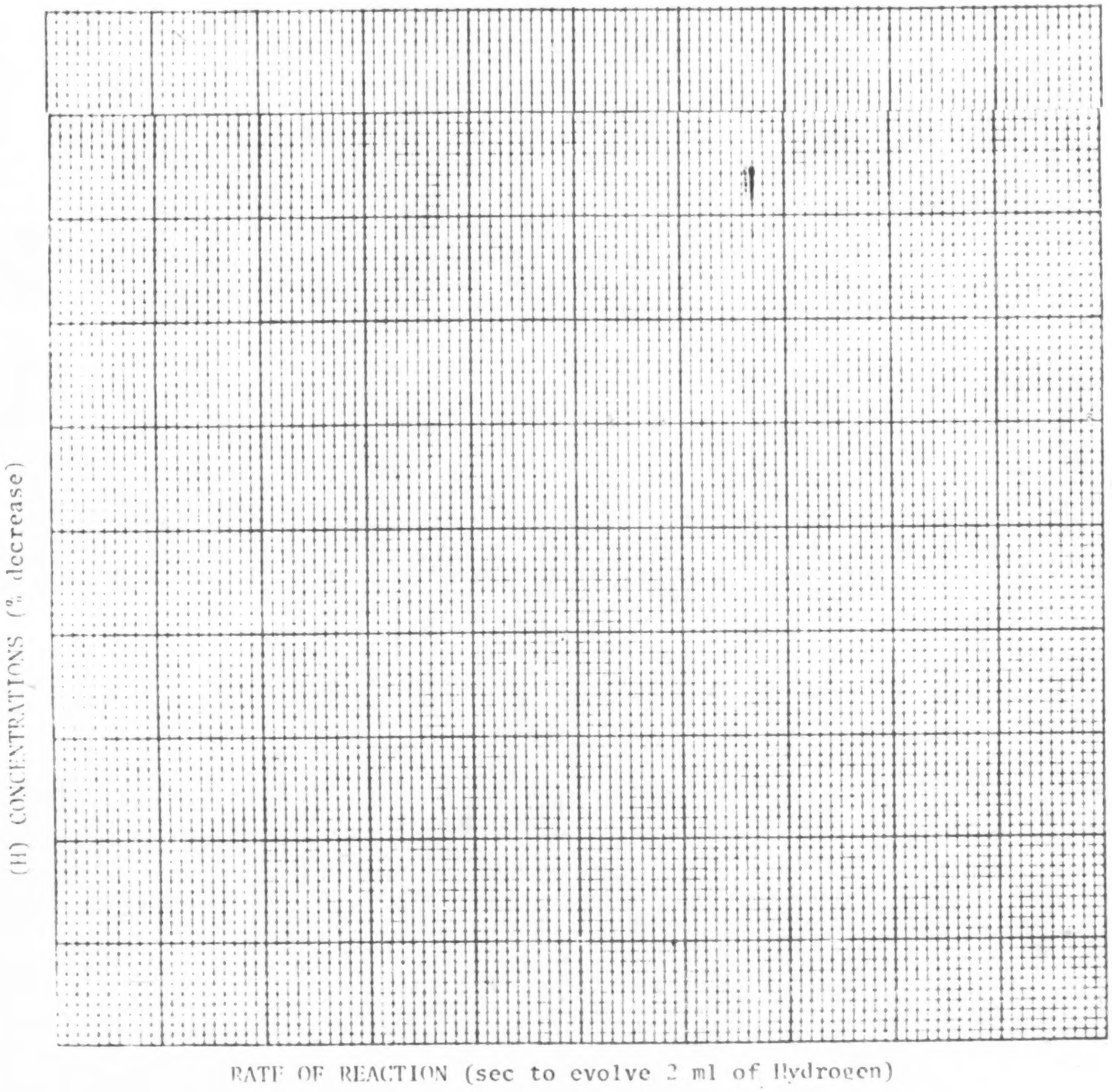
(H) = ____________ Grams $NH_4C_2H_3O_2$ added = ____________

volume hydrogen (ml)	1	2	3	4	5
time (sec)					

Class Summary of Data:

Reductions in (H^+) Concentration	Rate of Reaction (sec to evolve 2 ml of hydrogen)
0.1N Standard	
10%	
20	
30	
40	
50	
60	
70	
80	
90	

Represent the rate of reaction as a function of hydrogen ion concentration.



QUESTIONS:

1. Write the net ionic equation for the replacement of hydrogen in acetic acid by magnesium.

2. How is the rate of this reaction affected by the (H)?

3. Calculate the pH of the acetic acid solution which has had its (H) reduced to 40% of its value for the 0.1M standard solution.

4. What weight of $NH_4C_2H_3O_2$ salt would be required to reduce the (H) of the 0.1M $HC_2H_3O_2$ solution to zero?

5. How could one account for the fact that the ion concentration does not grossly affect the rate of chemical reaction until the concentration of one species is reduced to a few percentage points of the original concentration?

Problem Exercise

Name ____________________
Science IIIA Hour ________
Date Due ____________________

SOLUBILITY PRODUCTS

1. A solution in equilibrium with a precipitate of AgCl was found, on analysis, to contain 1.0×10^{-4} mole of Ag^+ per liter and 1.7×10^{-6} mole of Cl^- per liter. Calculate the solubility product for AgCl.

2. A solution in equilibrium with a precipitate of Ag_2S was found, on analysis, to contain 6.3×10^{-18} mole of S^{--} per liter and 1.26×10^{-17} mole of Ag^+ per liter. Calculate the solubility product for Ag_2S.

3. A solution in equilibrium with a precipitate of Ag_3PO_4 was found on analysis to contain 1.6×10^{-5} mole of PO_4^{---} per liter and 4.8×10^{-5} mole of Ag^+ per liter. Calculate the solubility product for Ag_3PO_4.

4. In each of the following a saturated solution was prepared by shaking the pure solid compound with pure water. The solubilities obtained are given. From these solubilities, calculate the solubility product of each solute.

   a. AgCl = 1.67×10^{-5} mole AgCl per liter -

   b. Ag_2SO_4 = 1.4×10^{-2} mole Ag_2SO_4 per liter -

5. What concentration of Ag^+ in moles per liter, must be present to just start precipitation of AgCl from a solution containing 1.0×10^{-4} mole of Cl^- per liter? The solubility product of AgCl is 2.8×10^{-10}.

6. What concentration of OH^-, in moles per liter, is necessary to start precipitation of $Fe(OH)_3$ from a solution containing 2×10^{-6} mole of Fe^{+++} per liter? The solubility product of $Fe(OH)_3$ is 6×10^{-38}.

7. A suspension of calcium hydroxide in water was found to have a pH of 12.3. Calculate the solubility product of $Ca(OH)_2$.

8. The solubility product of AgCl is 2.8×10^{-10}. How many moles of AgCl will dissolve in a liter of 0.010 N KCl? The KCl is 100% ionized.

9. A solution in equilibrium with a precipitate of Ag_3PO_4 was found, on analysis, to contain 1.52×10^{-3} g of $PO_4^{\equiv}$ per liter and 5.18×10^{-3} g of Ag^+ per liter. Calculate the solubility product of Ag_3PO_4.

The laboratory investigation on pages 108-109 may be found

TITLE Chemistry, An Experimental Science

AUTHOR Chemical Education Materials Study

PUBLISHER W. H. Freeman & Company

PAGE NO. 46-47

PERIODIC CHART

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d

LIGHT METALS

TRANSITION

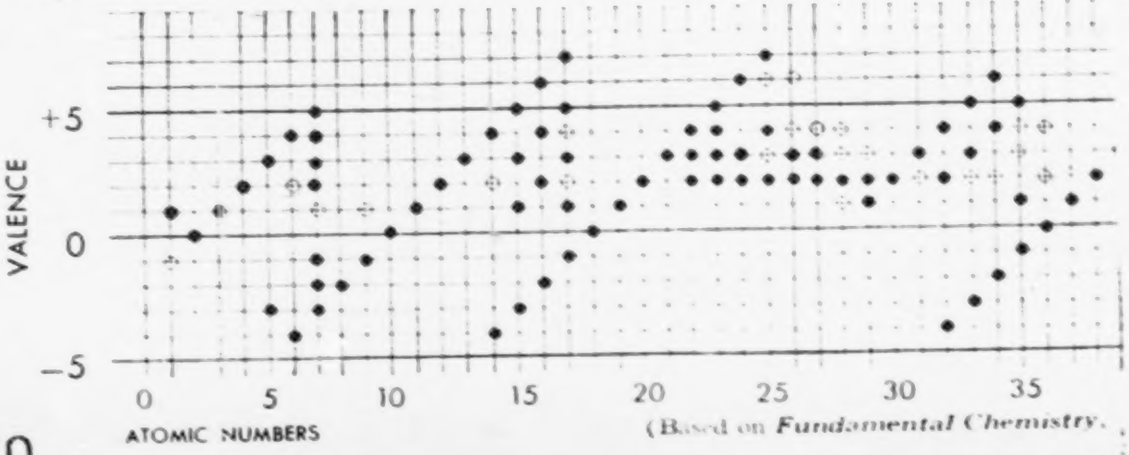
SHELLS PRINCIPAL QUANTUM No. *n*	SHELLS X-RAY NOTATION	I A		II A		III B		IV B		V B		VI B		VII B	
1	K	1	1 H 1.00797												
2	L	2 1	3 Li 6.939	2 2	4 Be 9.0122										
3	M	2 8 1	11 Na 22.9898	2 8 2	12 Mg 24.312										
4	N	2 8 8 1	19 K 39.102	2 8 8 2	20 Ca 40.08	2 8 9 2	21 Sc 44.956	2 8 10 2	22 Ti 47.90	2 8 11 2	23 V 50.942	2 8 13 1	24 Cr 51.996	2 8 13 2	25 Mn 54.9380
5	O	2 8 18 8 1	37 Rb 85.47	2 8 18 8 2	38 Sr 87.62	2 8 18 9 2	39 Y 88.905	2 8 18 10 2	40 Zr 91.22	2 8 18 12 1	41 Nb 92.906	2 8 18 13 1	42 Mo 95.94	2 8 18 13 2	43 Tc (99)
6	P	2 8 18 18 8 1	55 Cs 132.905	2 8 18 18 8 2	56 Ba 137.34	57-71 See Lanthanide Series		2 8 18 32 10 2	72 Hf 178.49	2 8 18 32 11 2	73 Ta 180.948	2 8 18 32 12 2	74 W 183.85	2 8 18 32 13 2	75 Re 186.2
7	Q	2 8 18 32 18 8 1	87 Fr (223)	2 8 18 32 18 8 2	88 Ra 226	89-100 See Actinide Series									

6	P	LANTHANIDE SERIES (Rare Earth Elements)
7	Q	ACTINIDE SERIES

NOTE: A value given in parentheses denotes the mass number of the isotope of the longest known half-life, or of the best known one.

*The brackets are meant to indicate only the general order of subshell filling. The filling of subshells is not completely regular, as is emphasized by the use of red ink to denote shells which have electron populations different from the preceding element. In the case of He, subshell population is not by itself indicative of chemical behavior, and that element is therefore included in the inert gas group, even though helium possesses no p-electrons.

Open circles represent valence states of minor importance, or those



(Based on *Fundamental Chemistry*,

OF THE ELEMENTS

REVISED, 1964

p

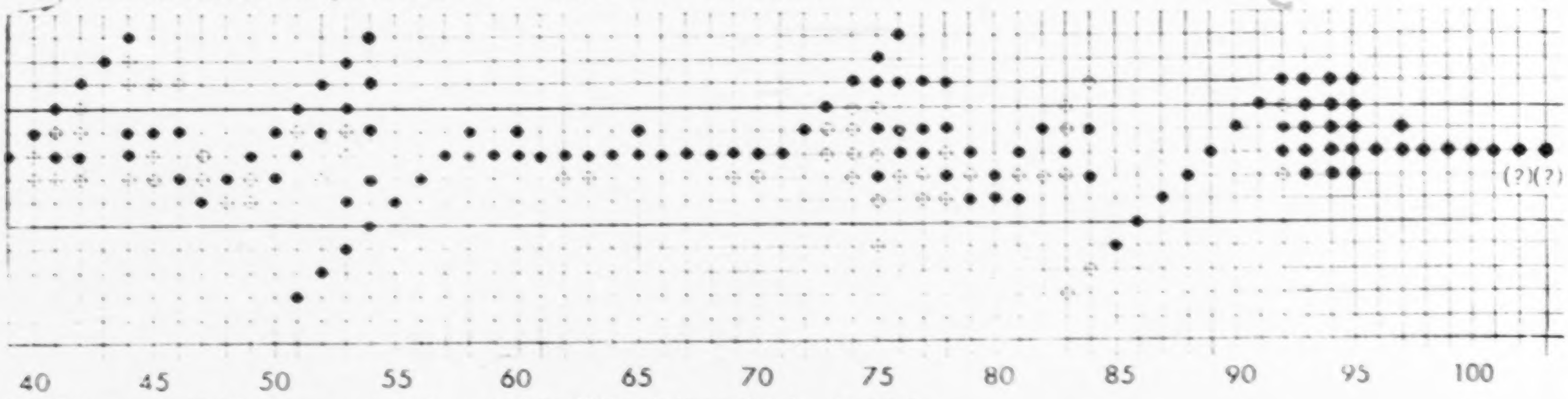
HEAVY METALS

NON METALS

VIII	VIII	VIII	I B	II B	III A	IV A	V A	VI A	VII A	INERT GASES
										2 2 He 4.0026
					2 3 5 B 10.811	2 4 6 C 12.01115	2 5 7 N 14.0067	2 6 8 O 15.9994	2 7 9 F 18.9984	2 8 10 Ne 20.183
					2 8 3 13 Al 26.9815	2 8 4 14 Si 28.086	2 8 5 15 P 30.9738	2 8 6 16 S 32.064	2 8 7 17 Cl 35.453	2 8 8 18 Ar 39.948
2 8 14 2 26 Fe 55.847	2 8 15 2 27 Co 58.9332	2 8 16 2 28 Ni 58.71	2 8 18 1 29 Cu 63.54	2 8 18 2 30 Zn 65.37	2 8 18 3 31 Ga 69.72	2 8 18 4 32 Ge 72.59	2 8 18 5 33 As 74.9216	2 8 18 6 34 Se 78.96	2 8 18 7 35 Br 79.909	2 8 18 8 36 Kr 83.80
2 8 18 15 1 44 Ru 101.07	2 8 18 16 1 45 Rh 102.905	2 8 18 18 46 Pd 106.4	2 8 18 18 1 47 Ag 107.870	2 8 18 18 2 48 Cd 112.40	2 8 18 18 3 49 In 114.82	2 8 18 18 4 50 Sn 118.69	2 8 18 18 5 51 Sb 121.75	2 8 18 18 6 52 Te 127.60	2 8 18 18 7 53 I 126.9044	2 8 18 18 8 54 Xe 131.30
2 8 18 32 14 2 76 Os 190.2	2 8 18 32 15 2 77 Ir 192.2	2 8 18 32 17 1 78 Pt 195.09	2 8 18 32 18 1 79 Au 196.967	2 8 18 32 18 2 80 Hg 200.59	2 8 18 32 18 3 81 Tl 204.37	2 8 18 32 18 4 82 Pb 207.19	2 8 18 32 18 5 83 Bi 208.980	2 8 18 32 18 6 84 Po (210)	2 8 18 32 18 7 85 At (210)	2 8 18 32 18 8 86 Rn (222)

d	f	f	f	f	f	f	f	f	f	f	f	f	f	f
2 8 18 18 9 2 57 La 138.91	2 8 18 19 9 2 58 Ce 140.12	2 8 18 21 8 2 59 Pr 140.907	2 8 18 22 8 2 60 Nd 144.24	2 8 18 23 8 2 61 Pm (147)	2 8 18 24 8 2 62 Sm 150.35	2 8 18 25 8 2 63 Eu 151.96	2 8 18 25 9 2 64 Gd 157.25	2 8 18 26 9 2 65 Tb 158.924	2 8 18 28 8 2 66 Dy 162.50	2 8 18 29 8 2 67 Ho 164.930	2 8 18 30 8 2 68 Er 167.26	2 8 18 31 8 2 69 Tm 168.934	2 8 18 32 8 2 70 Yb 173.04	2 8 18 32 9 2 71 Lu 174.97
2 8 18 32 18 9 2 89 Ac (227)	2 8 18 32 18 10 2 90 Th 232.038	2 8 18 32 20 9 2 91 Pa (231)	2 8 18 32 21 9 2 92 U 238.03	2 8 18 32 22 9 2 93 Np (237)	2 8 18 32 23 9 2 94 Pu (244)	2 8 18 32 24 9 2 95 Am (243)	2 8 18 32 25 9 2 96 Cm (247)	2 8 18 32 26 9 2 97 Bk (247)	2 8 18 32 27 9 2 98 Cf (251)	2 8 18 32 28 9 2 99 Es (254)	2 8 18 32 29 9 2 100 Fm (253)	2 8 18 32 30 9 2 101 Md (256)	102 No (254)	103 Lw (257)

unobtainable in presence of water. For transuranian elements, all valences reported are listed.



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